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(54) **MODULATION OF HUNTINGTIN EXPRESSION**

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(51) **Int. Cl.**
***C07H 21/04*** (2006.01)
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(52) **U.S. Cl.**
CPC .......... ***C12N 15/113*** (2013.01); *C12N 2310/11* (2013.01); *C12N 2310/113* (2013.01); *C12N 2310/315* (2013.01); *C12N 2310/321* (2013.01); *C12N 2310/3341* (2013.01); *C12N 2310/341* (2013.01); *C12N 2310/345* (2013.01); *C12N 2310/346* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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(57) **ABSTRACT**

Provided herein are methods, compounds, and compositions for reducing expression of huntingtin mRNA and protein in an animal. Such methods, compounds, and compositions are useful to treat, prevent, delay, or ameliorate Huntington's disease, or a symptom thereof.

**14 Claims, 10 Drawing Sheets**

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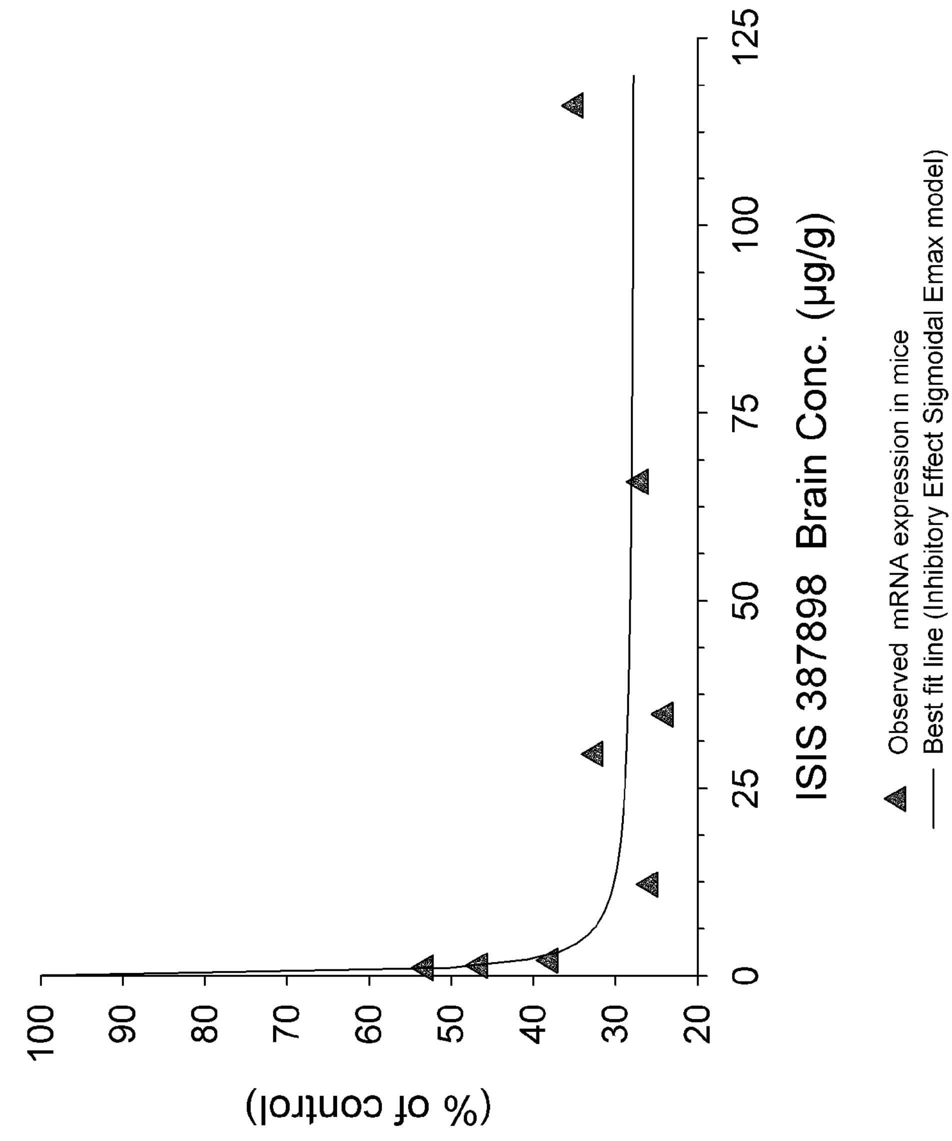

mRNA Expression
(% of control)
100
90
80
70
60
50
40
30
20
0
25
50
75
100
125
ISIS 387898 Brain Conc. (µg/g)
Observed mRNA expression in mice
Best fit line (Inhibitory Effect Sigmoidal Emax model)

Figure 1

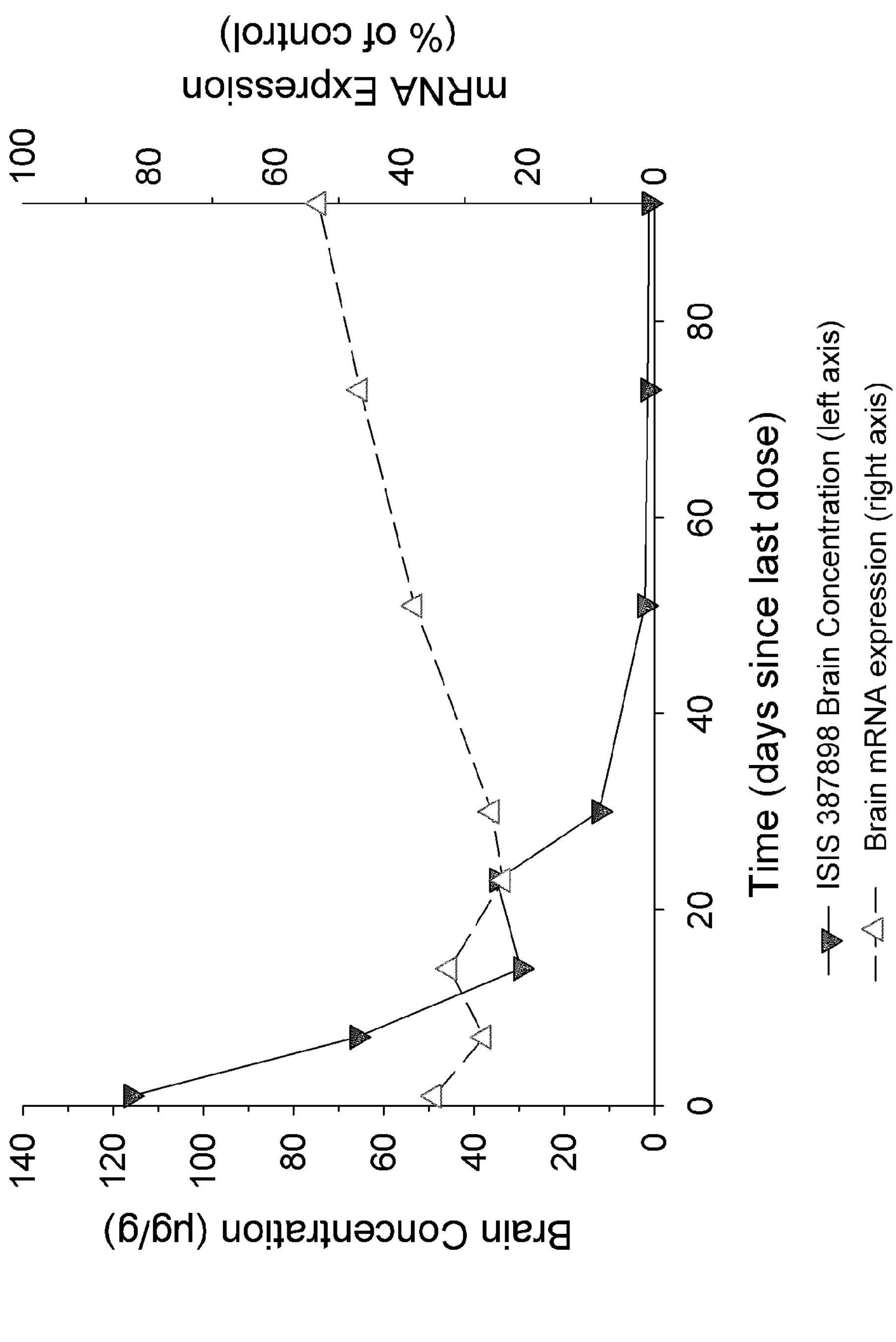

Brain Concentration (µg/g)
mRNA Expression (% of control)
Time (days since last dose)
ISIS 387898 Brain Concentration (left axis)
Brain mRNA expression (right axis)

Figure 2

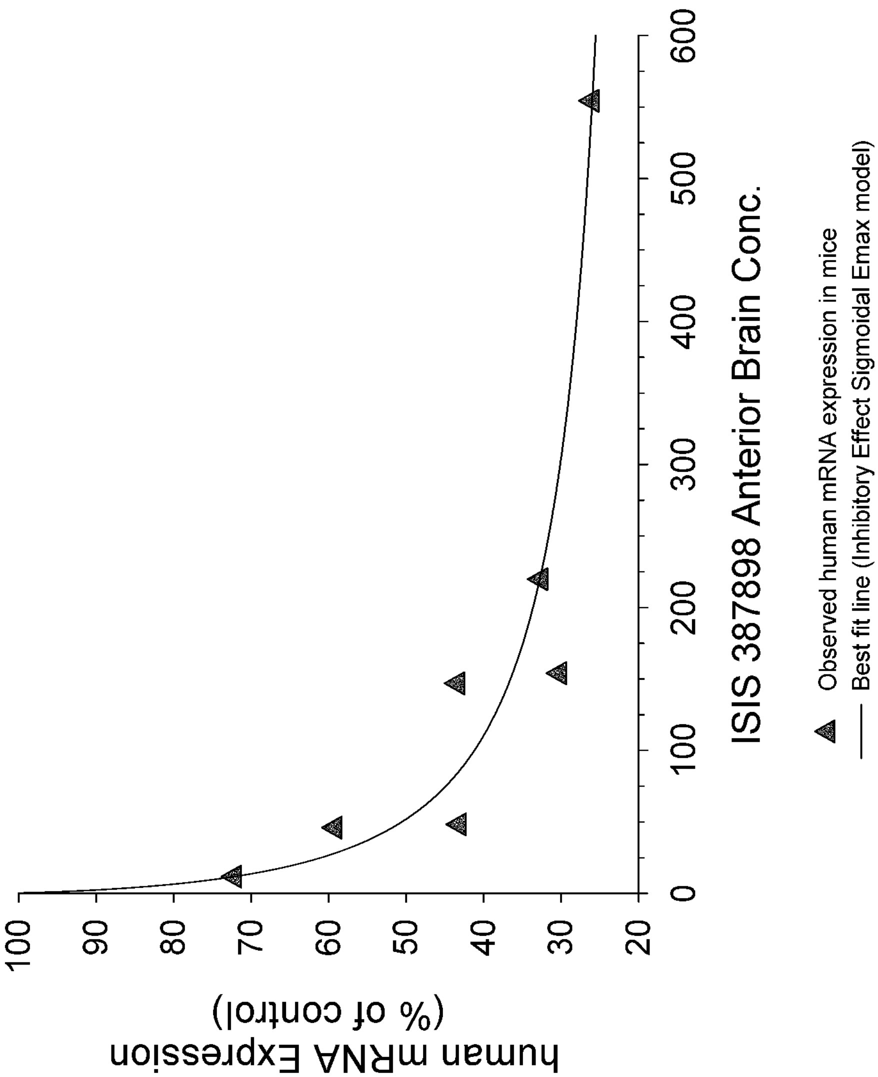

human mRNA Expression
(% of control)
100
90
80
70
60
50
40
30
20
0
100
200
300
400
500
600
ISIS 387898 Anterior Brain Conc.
Observed human mRNA expression in mice
Best fit line (Inhibitory Effect Sigmoidal Emax model)

Figure 3

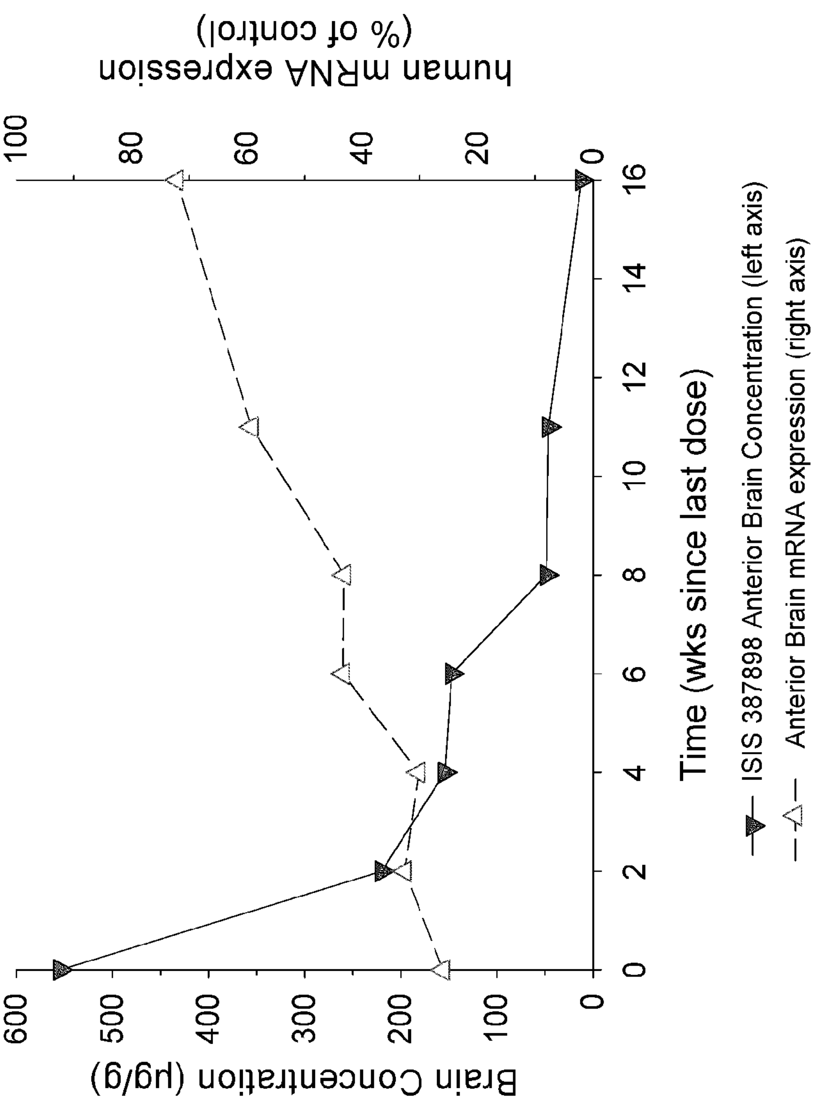

Brain Concentration (µg/g)
human mRNA expression (% of control)
Time (wks since last dose)
0
100
200
300
400
500
600
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
ISIS 387898 Anterior Brain Concentration (left axis)
Anterior Brain mRNA expression (right axis)

Figure 4

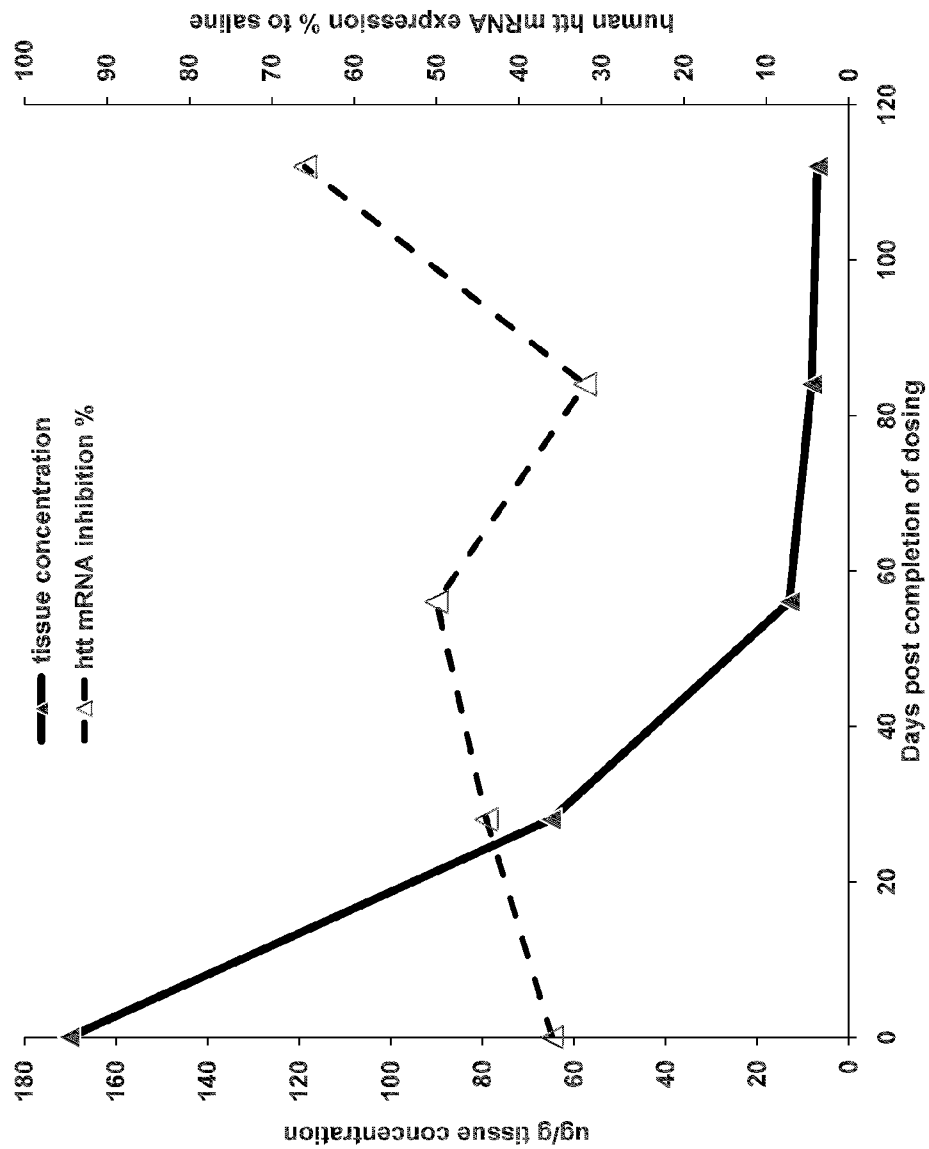

tissue concentration
htt mRNA inhibition %
ug/g tissue concentration
human htt mRNA expression % to saline
Days post completion of dosing

Figure 5

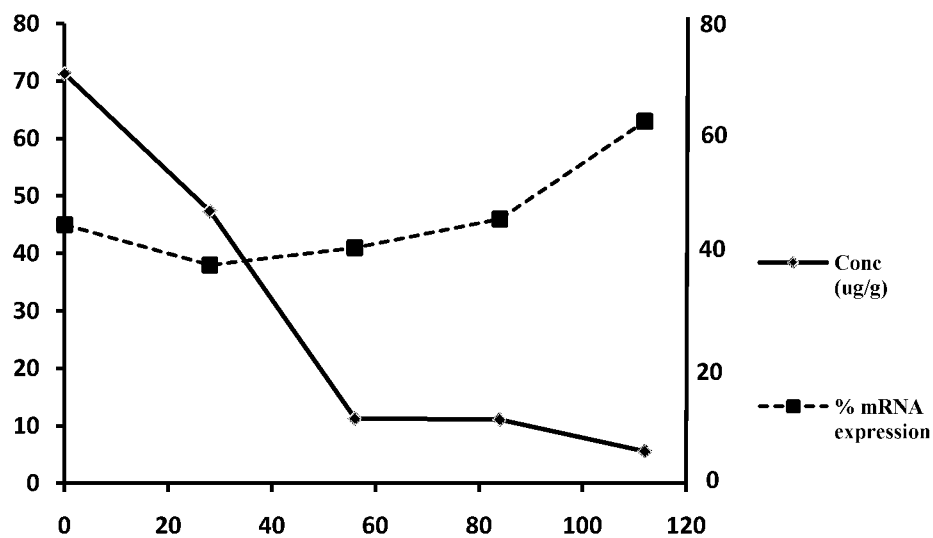

80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
80
60
40
20
0
Conc (ug/g)
% mRNA expression

Figure 6

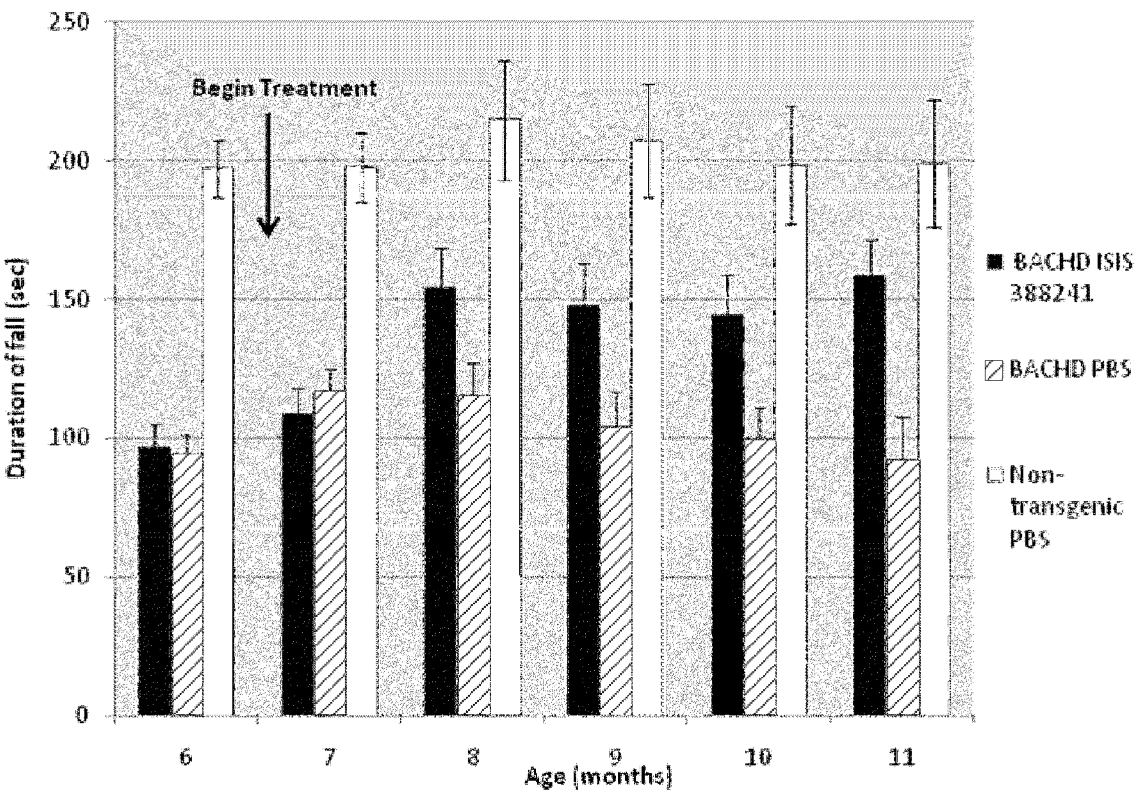

250
200
150
100
50
0
Begin Treatment
Duration of fall (sec)
6
7
8
9
10
11
Age (months)
BACHD ISIS 388241
BACHD PBS
Non-transgenic PBS

Figure 7

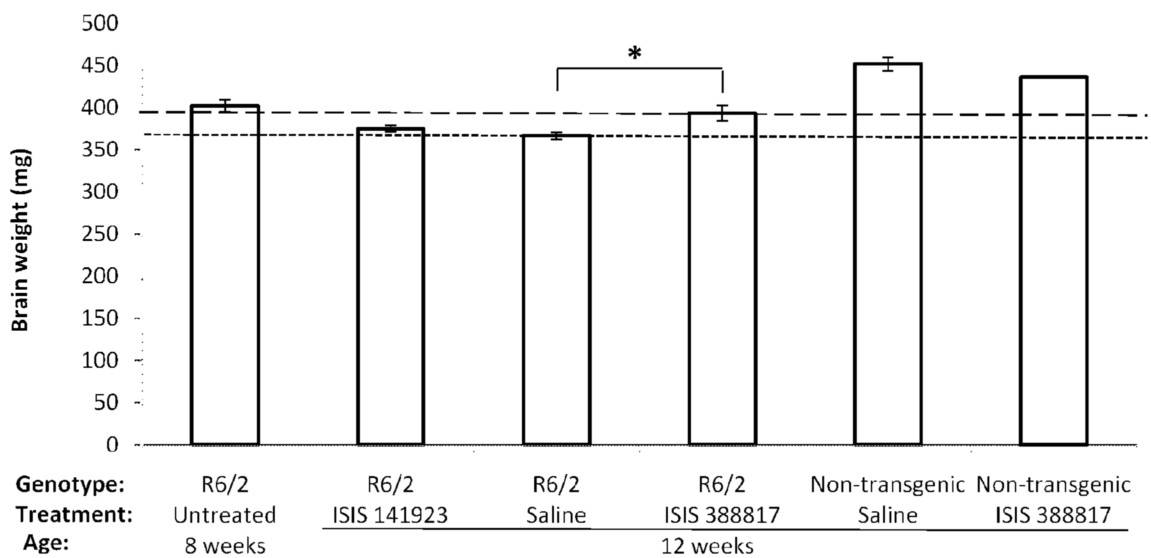

500
450
400
350
300
250
200
150
100
50
0
Brain weight (mg)
*
Genotype:
Treatment:
Age:
R6/2
Untreated
8 weeks
R6/2
ISIS 141923
R6/2
Saline
R6/2
ISIS 388817
Non-transgenic
Saline
Non-transgenic
ISIS 388817
12 weeks

Figure 8

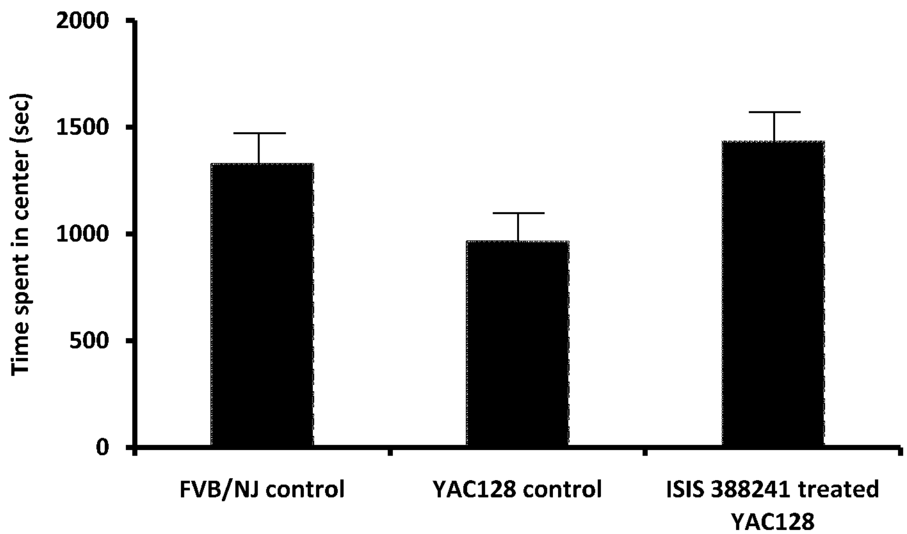

2000
1500
1000
500
0
Time spent in center (sec)
FVB/NJ control
YAC128 control
ISIS 388241 treated YAC128

Figure 9

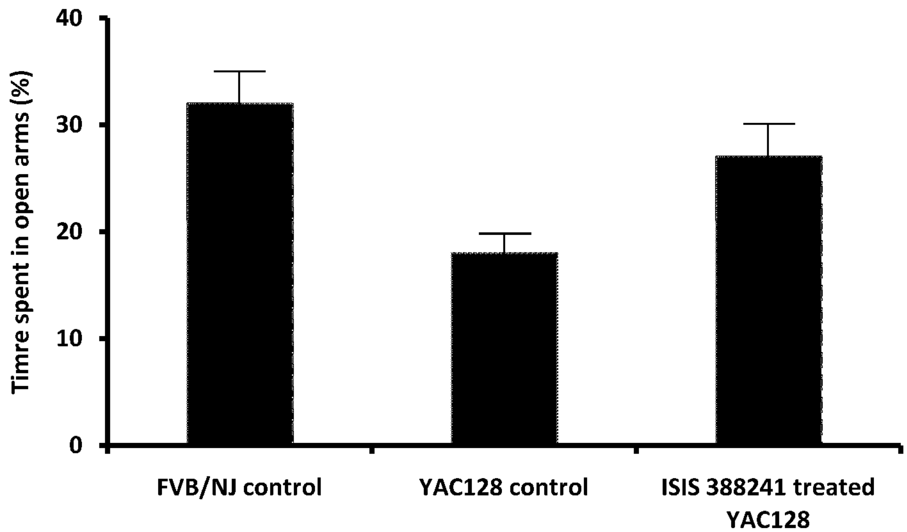

40
30
20
10
0
Timre spent in open arms (%)
FVB/NJ control
YAC128 control
ISIS 388241 treated YAC128

Figure 10

# MODULATION OF HUNTINGTIN EXPRESSION

## RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/395,188, filed May 30, 2012, which is the National Stage application filed under 35 U.S.C. 371 of International Application No. PCT/US2010/048532, filed Sep. 10, 2010, which claims benefit of priority to U.S. provisional application No. 61/241,583, filed Sep. 11, 2009, each of which is herein incorporated in its entirety.

## SEQUENCE LISTING

The present application is being filed along with a Sequence Listing in electronic format. The Sequence Listing is provided as a file entitled BIOL0113USC1SEQ_ST25.txt created Oct. 29, 2014, which is 488 Kb in size. The information in the electronic format of the sequence listing is incorporated herein by reference in its entirety.

## FIELD OF THE INVENTION

Provided herein are methods, compounds, and compositions for reducing expression of huntingtin mRNA and protein in an animal. Such methods, compounds, and compositions are useful, for example, to treat, prevent, or ameliorate Huntington's disease.

## BACKGROUND

Huntington's disease (HD) is a devastating autosomal dominant, neurodegenerative disease caused by a CAG trinucleotide repeat expansion encoding an abnormally long polyglutamine (PolyQ) tract in the huntingtin protein. The Huntington disease gene was first mapped in 1993 (The Huntington's Disease Collaborative Research Group. Cell. 1993, 72:971-83), consisting of a gene, IT15, which contained a polymorphic trinucleotide repeat that is expanded and unstable on HD chromosomes. Although CAG repeats in the normal size range are usually inherited as Mendelian alleles, expanded HD repeats are unstable through meiotic transmission and are found to be expanded beyond the normal size range (6-34 repeat units) in HD patients.

Both normal and variant huntingtin protein are localized chiefly in the cytoplasm of neurons (DiFiglia et al., Neuron 1995, 14:1075-81). As a result of excessive polyglutamine length, huntingtin protein forms aggregates in the cytoplasm and nucleus of CNS neurons (Davies et al., Cell 1997, 90:537-548). Both transgenic animals and genetically modified cell lines have been used to investigate the effects of expanded polyQ repeats on the localization and processing of huntingtin. However, it is still unclear whether the formation of aggregates per se is the essential cytotoxic step or a consequence of cellular dysfunction.

HD is characterized by progressive chorea, psychiatric changes and intellectual decline. This dominant disorder affects males and females equally, and occurs in all races (Gusella and MacDonald, Curr. Opin. Neurobiol. 1995 5:656-62). Symptoms of HD are due to the death of neurons in many brain regions, but is most apparent in the striatum, particularly in the caudate nucleus, which suffers a progressive gradient of cell loss that ultimately decimates the entire structure. Although the gene encoding huntingtin is expressed ubiquitously (Strong, T. V. et al., Nat. Genet. 1995, 5:259-263), selective cell loss and fibrillary astrocytosis is observed in the brain, particularly in the caudate and putamen of the striatum and in the cerebral cortex of HD patients (Vonsattel, J-P. et al., Neuropathol. Exp. Neurol. 1985, 44:559-577), and, to a lesser extent, in the hippocampus (Spargo, E. et al., J. Neurol. Neurosurg. Psychiatry 1993, 56:487-491) and the subthalamus (Byers, R. K. et al., Neurology 1973, 23:561-569).

Huntingtin is crucial for normal development and may be regarded as a cell survival gene (Nasir et al., Human Molecular Genetics, Vol 5, 1431-1435). The normal function of huntingtin remains incompletely characterized, but based upon protein-protein interactions, it appears to be associated with the cytoskeleton and required for neurogenesis (Walling et al., J. Neurosci Res. 1998, 54:301-8). Huntingtin is specifically cleaved during apoptosis by a key cysteine protease, apopain, known to play a pivotal role in apoptotic cell death. The rate of cleavage is enhanced by longer polyglutamine tracts, suggesting that inappropriate apoptosis underlies HD.

Antisense technology is emerging as an effective means for reducing the expression of specific gene products and may therefore prove to be uniquely useful in a number of therapeutic, diagnostic, and research applications for the modulation of huntingtin expression. (See U.S. Patent Publication Nos. 2008/0039418 and 2007/0299027)

Antisense compounds for modulating expression of huntingtin are disclosed in the aforementioned published patent applications. However, there remains a need for additional such compounds.

## SUMMARY OF THE INVENTION

Provided herein are methods, compounds, and compositions for modulating expression of huntingtin and treating, preventing, delaying or ameliorating Huntington's disease and/or a symptom thereof.

## BRIEF DESCRIPTION OF THE FIGURES

FIG. **1**:

The PK/PD relationship of huntingtin mRNA expression in intrastriatal tissue with ISIS 387898 concentration in mouse brain. C57/BL6 mice were administered a single bolus of 50 μg of ISIS 387898 and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The $EC_{50}$ of ISIS 387898 was also calculated.

FIG. **2**:

Comparison of huntingtin mRNA expression in intrastriatal tissue and ISIS 387898 concentrations at various time points. C57/BL6 mice were administered a single bolus of 50 μg of ISIS 387898 and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The duration of action (as measured by htt mRNA expression) of ISIS 387898 (dashed line) was observed to be longer even after the concentration of the oligonucleotide (solid line) in the tissue.

FIG. **3**:

The PK/PD relationship of huntingtin mRNA expression in the anterior cortex tissue with ISIS 387898 concentration in mouse brain. BACHD mice were administered an intracerebroventricular infusion of 75 μg of ISIS 387898 for 2 weeks and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The $EC_{50}$ of ISIS 387898 was also calculated.

FIG. **4**:

Comparison of huntingtin mRNA expression in anterior cortex tissue and ISIS 387898 concentrations at various time points. BACHD mice were administered intracerebroventricular infusion of 75 μg of ISIS 387898 for 2 weeks, and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The duration of action (as measured by htt mRNA expression) of ISIS 387898 (dashed line) was observed to be longer even after the concentration of the oligonucleotide (solid line) in the tissue.

FIG. **5**:

Comparison of huntingtin mRNA expression in posterior cortex tissue and ISIS 388241 concentrations at various time points. BACHD mice were administered intracerebroventricular infusion of 50 μg of ISIS 388241 for 2 weeks, and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The duration of action (as measured by htt mRNA expression) of ISIS 388241 (dashed line) was observed to be longer even after the concentration of the oligonucleotide (solid line) in the tissue.

FIG. **6**:

Comparison of huntingtin mRNA expression in posterior cortex tissue and ISIS 443139 concentrations at various time points. BACHD mice were administered intracerebroventricular infusion of 50 μg of ISIS 443139 for 2 weeks, and huntingtin mRNA expression as well as the concentration of the antisense oligonucleotide in the tissue were measured. The duration of action (as measured by htt mRNA expression) of ISIS 443139 (dashed line) was observed to be longer even after the concentration of the oligonucleotide (solid line) in the tissue.

FIG. **7**.

Effect of antisense oligonucleotide treatment on the motor performance of BACHD mice using the Rotarod assay. BACHD mice were treated with 50 μg/day ICV of ISIS 388241 or PBS for two weeks. Control groups of non-transgenic littermates were similarly treated with ISIS 388241 or PBS. The accelerating Rotarod assay was then performed. Animals were placed on the Rotarod at a speed of 2 RPM; the Rotarod accelerated to 40 RPM over 5 minutes. The duration to fall was recorded. Baseline values at 6 months age were taken before the treatment and the time points given are the age of the mice at which the assay was conducted. The bars represent the duration to fall in seconds by BACHD mice treated with ISIS 388241 (black); by BACHD mice treated with PBS (hashed); and by non-transgenic littermates treated with PBS (white). ISIS 388241-treated mice displayed increased duration of fall and, therefore, improved motor performance on the Rotarod, compared to the PBS control.

FIG. **8**.

Effect of antisense oligonucleotide treatment on brain weight of R6/2 mice. Six-month old R6/2 mice were treated with 50 μg/day ICV of ISIS 388817 or control oligonucleotide ISIS 141923 or PBS for 4 weeks. Control groups of non-transgenic littermates were similarly treated with ISIS 388817 or PBS. A control group of eight-week old pre-symptomatic R6/2 mice were included in the study and not given any treatment. The bars represent the brain weights of eight-week old untreated R6/2 mice; R6/2 mice treated with ISIS 141923; R6/2 mice treated with PBS; R6/2 mice treated with ISIS 388817; non-transgenic littermates treated with PBS; and non-transgenic littermates treated with ISIS 388817. There was an increase in brain weight of R6/2 mice treated with ISIS 388817 compared to the PBS control.

FIG. **9**

Behavioral characterization of antisense oligonucleotide-treated YAC128 mice using the Open Field assay. Five month old YAC128 mice were treated with 50 μg/day ICV of ISIS 388241 or control oligonucleotide ISIS 141923 or PBS for 14 days. A control group of non-transgenic FVB/NJ littermates were included in the study and not given any treatment. Mice were placed in an open field arena that uses photobeam breaks to measure horizontal and vertical movement over a 30 min test session. Data was analyzed using Activity Monitor software to examine total ambulatory movement within the arena and movement within the center of the arena as a measure of anxiety. The bars represent time in seconds spent at the center of the field by FVB/NJ mice, YAC128 treated with PBS, and, YAC128 mice treated with ISIS 388241. YAC128 mice treated with ISIS 388241 spent more time in the center and were therefore deemed less anxiety-prone than the PBS control.



FIG. **10**

Behavioral characterization of antisense oligonucleotide-treated YAC128 mice using the Elevated Plus Maze assay. Five month old YAC128 mice were treated with 50 μg/day ICV of ISIS 388241 or control oligonucleotide ISIS 141923 or with PBS for 14 days. A control group of non-transgenic FVB/NJ littermates were included as untreated control. Mice were placed in the center of an apparatus which consisted of two open arms and two closed arms each measuring 659×6.25 cm and elevated 50 cm above the ground. The location of the mice on the apparatus and amount of time spent in the open arms was recorded over a 5 minute test session as a measure of anxiety. The bars represent the percentage of time spent in the open arms by FVB/NJ control, YAC128 treated with PBS, and YAC128 mice treated with ISIS 388241. YAC128 mice treated with ISIS 388241 spent more time in the open arms and were therefore deemed less anxiety-prone than the PBS control.

## DETAILED DESCRIPTION OF THE INVENTION

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed. Herein, the use of the singular includes the plural unless specifically stated otherwise. As used herein, the use of "or" means "and/or" unless stated otherwise. Furthermore, the use of the term "including" as well as other forms, such as "includes" and "included", is not limiting. Also, terms such as "element" or "component" encompass both elements and components comprising one unit and elements and components that comprise more than one subunit, unless specifically stated otherwise.

The section headings used herein are for organizational purposes only and are not to be construed as limiting the subject matter described. All documents, or portions of documents, cited in this application, including, but not limited to, patents, patent applications, articles, books, and treatises, are hereby expressly incorporated by reference for the portions of the document discussed herein, as well as in their entirety.

### Definitions

Unless specific definitions are provided, the nomenclature utilized in connection with, and the procedures and techniques of, analytical chemistry, synthetic organic chemistry, and medicinal and pharmaceutical chemistry described herein are those well known and commonly used in the art. Standard techniques may be used for chemical synthesis, and chemical analysis. Where permitted, all patents, applications, published applications and other publications, GENBANK Accession Numbers and associated sequence information obtainable through databases such as National Center for

Biotechnology Information (NCBI) and other data referred to throughout in the disclosure herein are incorporated by reference for the portions of the document discussed herein, as well as in their entirety.

Unless otherwise indicated, the following terms have the following meanings:

"2'-O-methoxyethyl" (also 2'-MOE and 2'-O$(CH_2)_2$—$OCH_3$) refers to an O-methoxy-ethyl modification of the 2' position of a furosyl ring. A 2'-O-methoxyethyl modified sugar is a modified sugar.

"2'-O-methoxyethyl nucleotide" means a nucleotide comprising a 2'-O-methoxyethyl modified sugar moiety.

"5-methylcytosine" means a cytosine modified with a methyl group attached to the 5' position. A 5-methylcytosine is a modified nucleobase.

"Active pharmaceutical agent" means the substance or substances in a pharmaceutical composition that provide a therapeutic benefit when administered to an individual. For example, in certain embodiments an antisense oligonucleotide targeted to huntingtin is an active pharmaceutical agent.

"Active target region" or "target region" means a region to which one or more active antisense compounds is targeted. "Active antisense compounds" means antisense compounds that reduce target nucleic acid levels or protein levels.

"Administered concomitantly" refers to the co-administration of two agents in any manner in which the pharmacological effects of both are manifest in the patient at the same time. Concomitant administration does not require that both agents be administered in a single pharmaceutical composition, in the same dosage form, or by the same route of administration. The effects of both agents need not manifest themselves at the same time. The effects need only be overlapping for a period of time and need not be coextensive.

"Administering" means providing a pharmaceutical agent to an individual, and includes, but is not limited to administering by a medical professional and self-administering.

"Amelioration" refers to a lessening of at least one indicator, sign, or symptom of an associated disease, disorder, or condition. The severity of indicators may be determined by subjective or objective measures, which are known to those skilled in the art.

"Animal" refers to a human or non-human animal, including, but not limited to, mice, rats, rabbits, dogs, cats, pigs, and non-human primates, including, but not limited to, monkeys and chimpanzees.

"Antisense activity" means any detectable or measurable activity attributable to the hybridization of an antisense compound to its target nucleic acid. In certain embodiments, antisense activity is a decrease in the amount or expression of a target nucleic acid or protein encoded by such target nucleic acid.

"Antisense compound" means an oligomeric compound that is capable of undergoing hybridization to a target nucleic acid through hydrogen bonding.

"Antisense inhibition" means reduction of target nucleic acid levels or target protein levels in the presence of an antisense compound complementary to a target nucleic acid compared to target nucleic acid levels or target protein levels in the absence of the antisense compound.

"Antisense oligonucleotide" means a single-stranded oligonucleotide having a nucleobase sequence that permits hybridization to a corresponding region or segment of a target nucleic acid.

"Bicyclic sugar" means a furosyl ring modified by the bridging of two non-geminal ring atoms. A bicyclic sugar is a modified sugar.

"Bicyclic nucleic acid" or "BNA" refers to a nucleoside or nucleotide wherein the furanose portion of the nucleoside or nucleotide includes a bridge connecting two carbon atoms on the furanose ring, thereby forming a bicyclic ring system.

"Cap structure" or "terminal cap moiety" means chemical modifications, which have been incorporated at either terminus of an antisense compound.

"Chemically distinct region" refers to a region of an antisense compound that is in some way chemically different than another region of the same antisense compound. For example, a region having 2'-O-methoxyethyl nucleotides is chemically distinct from a region having nucleotides without 2'-O-methoxyethyl modifications.

"Chimeric antisense compound" means an antisense compound that has at least two chemically distinct regions.

"Co-administration" means administration of two or more pharmaceutical agents to an individual. The two or more pharmaceutical agents may be in a single pharmaceutical composition, or may be in separate pharmaceutical compositions. Each of the two or more pharmaceutical agents may be administered through the same or different routes of administration. Co-administration encompasses parallel or sequential administration.

"Complementarity" means the capacity for pairing between nucleobases of a first nucleic acid and a second nucleic acid.

"Contiguous nucleobases" means nucleobases immediately adjacent to each other.

"Diluent" means an ingredient in a composition that lacks pharmacological activity, but is pharmaceutically necessary or desirable. For example, the diluent in an injected composition may be a liquid, e.g. saline solution.

"Dose" means a specified quantity of a pharmaceutical agent provided in a single administration, or in a specified time period. In certain embodiments, a dose may be administered in one, two, or more boluses, tablets, or injections. For example, in certain embodiments where subcutaneous administration is desired, the desired dose requires a volume not easily accommodated by a single injection, therefore, two or more injections may be used to achieve the desired dose. In certain embodiments, the pharmaceutical agent is administered by infusion over an extended period of time or continuously. Doses may be stated as the amount of pharmaceutical agent per hour, day, week, or month.

"Effective amount" means the amount of active pharmaceutical agent sufficient to effectuate a desired physiological outcome in an individual in need of the agent. The effective amount may vary among individuals depending on the health and physical condition of the individual to be treated, the taxonomic group of the individuals to be treated, the formulation of the composition, assessment of the individual's medical condition, and other relevant factors.

"Huntingtin nucleic acid" means any nucleic acid encoding huntingtin. For example, in certain embodiments, a huntingtin nucleic acid includes a DNA sequence encoding huntingtin, an RNA sequence transcribed from DNA encoding huntingtin (including genomic DNA comprising introns and exons), and an mRNA sequence encoding huntingtin. "Huntingtin mRNA" means an mRNA encoding a huntingtin protein.

"Fully complementary" or "100% complementary" means each nucleobase of a nucleobase sequence of a first nucleic acid has a complementary nucleobase in a second nucleobase sequence of a second nucleic acid. In certain embodiments, a first nucleic acid is an antisense compound and a target nucleic acid is a second nucleic acid.

"Gapmer" means a chimeric antisense compound in which an internal region having a plurality of nucleosides that support RNase H cleavage is positioned between external regions having one or more nucleosides, wherein the nucleosides comprising the internal region are chemically distinct from the nucleoside or nucleosides comprising the external regions. The internal region may be referred to as a "gap segment" and the external regions may be referred to as "wing segments."

"Gap-widened" means a chimeric antisense compound having a gap segment of 12 or more contiguous 2'-deoxyribonucleosides positioned between and immediately adjacent to 5' and 3' wing segments having from one to six nucleosides.

"Hybridization" means the annealing of complementary nucleic acid molecules. In certain embodiments, complementary nucleic acid molecules include an antisense compound and a target nucleic acid.

"Immediately adjacent" means there are no intervening elements between the immediately adjacent elements.

"Individual" means a human or non-human animal selected for treatment or therapy.

"Internucleoside linkage" refers to the chemical bond between nucleosides.

"Linked nucleosides" means adjacent nucleosides which are bonded together.

"Mismatch" or "non-complementary nucleobase" refers to the case when a nucleobase of a first nucleic acid is not capable of pairing with the corresponding nucleobase of a second or target nucleic acid.

"Modified internucleoside linkage" refers to a substitution or any change from a naturally occurring internucleoside bond (i.e. a phosphodiester internucleoside bond).

"Modified nucleobase" refers to any nucleobase other than adenine, cytosine, guanine, thymidine, or uracil. An "unmodified nucleobase" means the purine bases adenine (A) and guanine (G), and the pyrimidine bases thymine (T), cytosine (C), and uracil (U).

"Modified nucleotide" means a nucleotide having, independently, a modified sugar moiety, modified internucleoside linkage, or modified nucleobase. A "modified nucleoside" means a nucleoside having, independently, a modified sugar moiety or modified nucleobase.

"Modified oligonucleotide" means an oligonucleotide comprising at least one modified nucleotide.

"Modified sugar" refers to a substitution or change from a natural sugar.

"Motif" means the pattern of chemically distinct regions in an antisense compound.

"Naturally occurring internucleoside linkage" means a 3' to 5' phosphodiester linkage.

"Natural sugar moiety" means a sugar found in DNA (2'-H) or RNA (2'-OH).

"Nucleic acid" refers to molecules composed of monomeric nucleotides. A nucleic acid includes ribonucleic acids (RNA), deoxyribonucleic acids (DNA), single-stranded nucleic acids, double-stranded nucleic acids, small interfering ribonucleic acids (siRNA), and microRNAs (miRNA). A nucleic acid may also comprise a combination of these elements in a single molecule.

"Nucleobase" means a heterocyclic moiety capable of pairing with a base of another nucleic acid.

"Nucleobase sequence" means the order of contiguous nucleobases independent of any sugar, linkage, or nucleobase modification.

"Nucleoside" means a nucleobase linked to a sugar.

"Nucleotide" means a nucleoside having a phosphate group covalently linked to the sugar portion of the nucleoside.

"Oligomeric compound" or "oligomer" means a polymer of linked monomeric subunits which is capable of hybridizing to at least a region of a nucleic acid molecule.

"Oligonucleotide" means a polymer of linked nucleosides each of which can be modified or unmodified, independent one from another.

"Parenteral administration" means administration through injection or infusion. Parenteral administration includes subcutaneous administration, intravenous administration, intramuscular administration, intraarterial administration, intraperitoneal administration, or intracranial administration, e.g. intrathecal or intracerebroventricular administration. Administration can be continuous, or chronic, or short or intermittent.

"Peptide" means a molecule formed by linking at least two amino acids by amide bonds. Peptide refers to polypeptides and proteins.

"Pharmaceutical composition" means a mixture of substances suitable for administering to an individual. For example, a pharmaceutical composition may comprise one or more active pharmaceutical agents and a sterile aqueous solution.

"Pharmaceutically acceptable salts" means physiologically and pharmaceutically acceptable salts of antisense compounds, i.e., salts that retain the desired biological activity of the parent oligonucleotide and do not impart undesired toxicological effects thereto.

"Phosphorothioate linkage" means a linkage between nucleosides where the phosphodiester bond is modified by replacing one of the non-bridging oxygen atoms with a sulfur atom. A phosphorothioate linkage is a modified internucleoside linkage.

"Portion" means a defined number of contiguous (i.e. linked) nucleobases of a nucleic acid. In certain embodiments, a portion is a defined number of contiguous nucleobases of a target nucleic acid. In certain embodiments, a portion is a defined number of contiguous nucleobases of an antisense compound.

"Prevent" refers to delaying or forestalling the onset or development of a disease, disorder, or condition for a period of time from minutes to indefinitely. Prevent also means reducing risk of developing a disease, disorder, or condition.

"Prodrug" means a therapeutic agent that is prepared in an inactive form that is converted to an active form within the body or cells thereof by the action of endogenous enzymes or other chemicals or conditions.

"Side effects" means physiological responses attributable to a treatment other than the desired effects. In certain embodiments, side effects include injection site reactions, liver function test abnormalities, renal function abnormalities, liver toxicity, renal toxicity, central nervous system abnormalities, myopathies, and malaise. For example, increased aminotransferase levels in serum may indicate liver toxicity or liver function abnormality. For example, increased bilirubin may indicate liver toxicity or liver function abnormality.

"Single-stranded oligonucleotide" means an oligonucleotide which is not hybridized to a complementary strand.

"Specifically hybridizable" refers to an antisense compound having a sufficient degree of complementarity between an antisense oligonucleotide and a target nucleic acid to induce a desired effect, while exhibiting minimal or no effects on non-target nucleic acids under conditions in which specific binding is desired, i.e. under physiological conditions in the case of in vivo assays and therapeutic treatments.

"Targeting" or "targeted" means the process of design and selection of an antisense compound that will specifically hybridize to a target nucleic acid and induce a desired effect.

"Target nucleic acid," "target RNA," and "target RNA transcript" all refer to a nucleic acid capable of being targeted by antisense compounds.

"Target segment" means the sequence of nucleotides of a target nucleic acid to which an antisense compound is targeted. "5' target site" refers to the 5'-most nucleotide of a target segment.

"3' target site" refers to the 3'-most nucleotide of a target segment.

"Therapeutically effective amount" means an amount of a pharmaceutical agent that provides a therapeutic benefit to an individual.

"Treat" refers to administering a pharmaceutical composition to effect an alteration or improvement of a disease, disorder, or condition.

"Unmodified nucleotide" means a nucleotide composed of naturally occurring nucleobases, sugar moieties, and internucleoside linkages. In certain embodiments, an unmodified nucleotide is an RNA nucleotide (i.e. β-D-ribonucleosides) or a DNA nucleotide (i.e. β-D-deoxyribonucleoside).

## Certain Embodiments

Certain embodiments provide methods, compounds, and compositions for inhibiting huntingtin expression.

Certain embodiments provide antisense compounds targeted to a huntingtin nucleic acid. In certain embodiments, the huntingtin nucleic acid is any of the sequences set forth in GENBANK Accession No. NM_002111.6 (incorporated herein as SEQ ID NO: 1), GENBANK Accession No. NT_006081.17 truncated from nucleotides 462000 to 634000 (incorporated herein as SEQ ID NO: 2), GENBANK Accession No. NM_010414.1 (incorporated herein as SEQ ID NO: 3), the complement of GENBANK Accession No. NW_001109716.1 truncated at nucleotides 698000 to 866000 (incorporated herein as SEQ ID NO: 4), and GENBANK Accession No. NM_024357.2 (incorporated herein as SEQ ID NO: 5).

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides wherein the linked nucleosides comprise at least 8 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22, 32. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, or at least 12 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22, 32. In certain embodiments, the nucleobase sequences are those recited in SEQ ID NOs: 24, 25, 26, 6, 12, 28, 21, 22, 32, 13. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, or at least 12 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 15 to 25 linked nucleosides wherein the linked nucleosides comprise at least 8 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22, 32. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, at least 12, at least 13, at least 14 or at least 15 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22, 32. In certain embodiments, the nucleobase sequences are those recited in SEQ ID NOs: 24, 25, 26, 6, 12, 28, 21, 22, 32, 13. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, at least 12, at least 13, at least 14 or at least 15 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 18 to 21 linked nucleosides wherein the linked nucleosides comprise at least 8 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22, and 32. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17 or at least 18 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22 and 32. In certain embodiments, the nucleobase sequences are those recited in SEQ ID NOs: 24, 25, 26, 6, 12, 28, 21, 22, 32, 13. In certain embodiments, the modified oligonucleotide comprises at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, or at least 18 contiguous nucleobases of a sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12-30 linked nucleosides wherein the linked nucleosides comprise at least an 8 contiguous nucleobase portion that is complementary within the region selected from nucleotides 4384-4403, 4605-4624, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4617-4636, 4622-4639, 4813-4832, 4814-4833, 4823-4842, 4860-4877, 4868-4887, 4925-4944, 4928-4947, 4931-4950, 4931-4948, 4955-4974, 4960-4977, 5801-5820, 5809-5828, 5809-5826, 101088-101105, 115066-115085, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4813-4832, 4862-4881, 5809-5828, 4928-4947 of SEQ ID NO: 1. In certain embodiments the region is selected from 4384-4403, 4609-4628, 4610-4629, 4860-4877, 4862-4881, 4925-4944, 4928-4947, 4931-4950, 4955-4974, and 5809-5828 of SEQ ID NO: 1. In certain embodiments the region is selected from 4862-4881, 4609-4628, 5809-5828, 5809-5826, 5801-5820, and 4955-4974. In certain embodiments, the modified oligonucleotide has at least a 9, at least a 10, at least an 11, or at least a 12 contiguous nucleobase portion of which is complementary within a region described herein.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 15-25 linked nucleosides wherein the linked nucleosides comprise at least an 8 contiguous nucleobase portion that is complementary within the region selected from nucleotides 4384-4403, 4609-4628, 4610-4629, 4860-4877, 4862-4881, 4925-4944, 4928-4947, 4931-4950, 4955-4974, and 5809-5829 of SEQ ID NO: 1. In certain embodiments, the modified oligonucleotide has at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, or at least a 15 contiguous nucleobase portion of which is complementary within a region described herein.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 15-25 linked nucleosides wherein the linked nucleosides comprise at least an 8 contiguous nucleobase portion that is complementary within the region selected from nucleotides 4862-4881, 4609-4628, 5809-5828, 5809-5826, 5801-5820, and 4955-4974. In certain embodiments, the modified oligonucleotide has at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, or at least a 15 contiguous nucleobase portion of which is complementary within a region described herein.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 18-21 linked nucleosides wherein the linked nucleosides comprise at least an 8 contiguous nucleobase portion that is complementary within the region selected from nucleotides 4384-4403, 4609-4628, 4610-4629, 4860-4877, 4862-4881, 4925-4944, 4928-4947, 4931-4950, 4955-4974, and 5809-5829 of SEQ ID NO: 1. In certain embodiments, the modified oligonucleotide has at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, at least a 14, at least a 15, at least a 16, at least a 17, or at least an 18 contiguous nucleobase portion of which is complementary within a region described herein.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 18-21 linked nucleosides wherein the linked nucleosides comprise at least an 8 contiguous nucleobase portion that is complementary within the region selected from nucleotides 4862-4881, 4609-4628, 5809-5828, 5809-5826, 5801-5820, and 4955-4974. In certain embodiments, the modified oligonucleotide has at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, at least a 14, at least a 15, at least a 16, at least a 17, or at least an 18 contiguous nucleobase portion of which is complementary within a region described herein.

In certain embodiments, the modified oligonucleotide consists of a single-stranded modified oligonucleotide.

In certain embodiments, the modified oligonucleotide consists of 20 linked nucleosides.

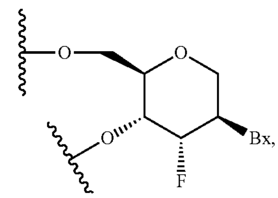
In certain embodiments, the nucleobase sequence of the modified oligonucleotide is at least 90% complementary over its entire length to a nucleobase sequence of SEQ ID NO: 1, 2, 3, 4 or 5. In certain embodiments, the nucleobase sequence of the modified oligonucleotide is at least 95% complementary over its entire length to a nucleobase sequence of SEQ ID NO: 1, 2, 3, 4 or 5. In certain embodiments, the modified oligonucleotide is at least 99% complementary over its entire length to SEQ ID NO: 1, 2, 3, 4 or 5. In certain embodiments, the nucleobase sequence of the modified oligonucleotide is 100% complementary over its entire length to a nucleobase sequence of SEQ ID NO: 1, 2, 3, 4 or 5.

In certain embodiments, the compound has at least one modified internucleoside linkage. In certain embodiments, the internucleoside linkage is a phosphorothioate internucleoside linkage.

In certain embodiments, the compound has at least one nucleoside comprising a modified sugar. In certain embodiments, the at least one modified sugar is a bicyclic sugar. In certain embodiments, the at least one bicyclic sugar comprises a 4'-CH($CH_3$)—O-2' bridge. In certain embodiments, the at least one modified sugar comprises a 2'-O-methoxyethyl.

In certain embodiments, the compound comprises at least one at least one tetrahydropyran modified nucleoside wherein a tetrahydropyran ring replaces the furanose ring. In certain embodiments, the at least one tetrahydropyran modified nucleoside has the structure:





wherein Bx is an optionally protected heterocyclic base moiety.

In certain embodiments, the compound has at least one nucleoside comprising a modified nucleobase. In certain embodiments, the modified nucleobase is a 5-methylcytosine.

In certain embodiments, the modified oligonucleotide of the compound comprises:

(i) a gap segment consisting of linked deoxynucleosides;
(ii) a 5' wing segment consisting of linked nucleosides;
(iii) a 3' wing segment consisting of linked nucleosides, wherein the gap segment is positioned between the 5' wing segment and the 3' wing segment and wherein each nucleoside of each wing segment comprises a modified sugar.

In certain embodiments, the modified oligonucleotide of the compound comprises:

(i) a gap segment consisting often linked deoxynucleosides;
(ii) a 5' wing segment consisting of five linked nucleosides;
(iii) a 3' wing segment consisting of five linked nucleosides, wherein the gap segment is positioned immediately adjacent to and between the 5' wing segment and the 3' wing segment, wherein each nucleoside of each wing segment comprises a 2'-O-methoxyethyl sugar; and wherein each internucleoside linkage is a phosphorothioate linkage.

In certain embodiments, the modified oligonucleotide of the compound comprises:

(i) a gap segment consisting of eight linked deoxynucleosides;
(ii) a 5' wing segment consisting of six linked nucleosides;
(iii) a 3' wing segment consisting of six linked nucleosides, wherein the gap segment is positioned immediately adjacent to and between the 5' wing segment and the 3' wing segment, wherein each nucleoside of each wing segment comprises a 2'-O-methoxyethyl sugar; and wherein each internucleoside linkage is a phosphorothioate linkage.

In certain embodiments, the modified oligonucleotide of the compound comprises:

(i) a gap segment consisting of eight linked deoxynucleosides;
(ii) a 5' wing segment consisting of five linked nucleosides;
(iii) a 3' wing segment consisting of five linked nucleosides, wherein the gap segment is positioned immediately adjacent to and between the 5' wing segment and the 3' wing segment, wherein each nucleoside of each wing segment comprises a 2'-O-methoxyethyl sugar; and wherein each internucleoside linkage is a phosphorothioate linkage.

Certain embodiments provide a composition comprising a compound as described herein, or a salt thereof, and a pharmaceutically acceptable carrier or diluent. In certain embodiments, the composition comprises a modified oligonucleotide consisting of 12 to 30 linked nucleosides and having a nucleobase sequence comprising at least 12 contiguous nucleobases of a nucleobase sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22 and 32 or a salt thereof and a pharmaceutically acceptable carrier or diluent.

Certain embodiments provide a composition comprising a compound as described herein, or a salt thereof, and a pharmaceutically acceptable carrier or diluent. In certain embodiments, the composition comprises a modified oligonucleotide consisting of 12 to 30 linked nucleosides and having a nucleobase sequence comprising at least 12 contiguous nucleobases of a nucleobase sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33 or a salt thereof and a pharmaceutically acceptable carrier or diluent.

Certain embodiments provide methods of treating, preventing, or ameliorating Huntington's disease.

Certain embodiments provide methods comprising administering to an animal a compound as described herein to an animal. In certain embodiments, the method comprises administering to an animal a modified oligonucleotide consisting of 12 to 30 linked nucleosides and having a nucleobase sequence comprising at least 8 contiguous nucleobases of a nucleobase sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22 and 32.

Certain embodiments provide methods comprising administering to an animal a compound as described herein to an animal. In certain embodiments, the method comprises administering to an animal a modified oligonucleotide consisting of 12 to 30 linked nucleosides and having a nucleobase sequence comprising at least 8 contiguous nucleobases of a nucleobase sequence selected from among the nucleobase sequences recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33.

In certain embodiments, the animal is a human.

In certain embodiments, the administering prevents, treats, ameliorates, or slows progression Huntington's disease as described herein.

In certain embodiments, the compound is co-administered with a second agent.

In certain embodiments, the compound and the second agent are administered concomitantly.

In certain embodiments, the administering is parenteral administration. In certain embodiments, the parenteral administration is intracranial administration. In certain embodiments, the intracranial administration is intrathecal or intracerebroventricular administration.

Certain embodiments further provide a method to reduce huntingtin mRNA or protein expression in an animal comprising administering to the animal a compound or composition as described herein to reduce huntingtin mRNA or protein expression in the animal. In certain embodiments, the animal is a human. In certain embodiments, reducing huntingtin mRNA or protein expression prevents, treats, ameliorates, or slows progression of Huntington's disease.

Certain embodiments provide a method for treating a human with Huntington's disease comprising identifying the human with the disease and administering to the human a therapeutically effective amount of a compound or composition as described herein. In certain embodiments, the treatment reduces a symptom selected from the group consisting of restlessness, lack of coordination, unintentionally initiated motions, unintentionally uncompleted motions, unsteady gait, chorea, rigidity, writhing motions, abnormal posturing, instability, abnormal facial expressions, difficulty chewing, difficulty swallowing, difficulty speaking, seizure, sleep disturbances, impaired planning, impaired flexibility, impaired abstract thinking, impaired rule acquisition, impaired initiation of appropriate actions, impaired inhibition of inappropriate actions, impaired short-term memory, impaired long-term memory, paranoia, disorientation, confusion, hallucination, dementia, a anxiety, depression, blunted affect, egocentrisms, aggression, compulsive behavior, irritability, suicidal ideation, reduced brain mass, muscle atrophy, cardiac failure, impaired glucose tolerance, weight loss, osteoporosis, and testicular atrophy.

Further provided is a method for reducing or preventing Huntington's disease comprising administering to a human a therapeutically effective amount compound or composition as described herein, thereby reducing or preventing Huntington's disease.

Further provided is a method for ameliorating a symptom of Huntington's disease, comprising administering to a human in need thereof a compound comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein said modified oligonucleotide specifically hybridizes to SEQ ID NO:1, 2, 3, 4 or 5, thereby ameliorating a symptom of Huntington's disease in the human.

Further provided is a method for reducing the rate of progression of a symptom associated with Huntington's Disease, comprising administering to a human in need thereof a compound comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein said modified oligonucleotide specifically hybridizes to SEQ ID NO: 1, 2, 3, 4 or 5, thereby reducing the rate of progression a symptom of Huntington's disease in the human.

Further provided is a method for reversing degeneration indicated by a symptom associated with Huntington's disease, administering to a human in need thereof a compound comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein said modified oligonucleotide specifically hybridizes to SEQ ID NO:1, 2, 3, 4 or 5, thereby reversing degeneration indicated by a symptom of Huntington's disease in the human.

In certain embodiments, the symptom is a physical, cognitive, psychiatric, or peripheral symptom. In certain embodiments, the symptom is a physical symptom selected from the group consisting of restlessness, lack of coordination, unintentionally initiated motions, unintentionally uncompleted motions, unsteady gait, chorea, rigidity, writhing motions, abnormal posturing, instability, abnormal facial expressions, difficulty chewing, difficulty swallowing, difficulty speaking, seizure, and sleep disturbances. In certain embodiments, the symptom is a cognitive symptom selected from the group consisting of impaired planning, impaired flexibility, impaired abstract thinking, impaired rule acquisition, impaired initiation of appropriate actions, impaired inhibition of inappropriate actions, impaired short-term memory, impaired long-term memory, paranoia, disorientation, confusion, hallucination and dementia. In certain embodiments, the symptom is a psychiatric symptom selected from the group consisting of anxiety, depression, blunted affect, egocentrisms, aggression, compulsive behavior, irritability and suicidal ideation. In certain embodiments, the symptom is a peripheral symptom selected from the group consisting of reduced brain mass, muscle atrophy, cardiac failure, impaired glucose tolerance, weight loss, osteoporosis, and testicular atrophy.

Also provided are methods and compounds for the preparation of a medicament for the treatment, prevention, or amelioration of Huntington's disease.

Certain embodiments provide the use of a compound as described herein in the manufacture of a medicament for treating, ameliorating, or preventing Huntington's disease.

Certain embodiments provide a compound as described herein for use in treating, preventing, or ameliorating Huntington's disease as described herein by combination therapy with an additional agent or therapy as described herein. Agents or therapies can be co-administered or administered concomitantly.

Certain embodiments provide the use of a compound as described herein in the manufacture of a medicament for treating, preventing, or ameliorating Huntington's disease as described herein by combination therapy with an additional agent or therapy as described herein. Agents or therapies can be co-administered or administered concomitantly.

Certain embodiments provide the use of a compound as described herein in the manufacture of a medicament for treating, preventing, or ameliorating Huntington's disease as described herein in a patient who is subsequently administered an additional agent or therapy as described herein.

Certain embodiments provide a kit for treating, preventing, or ameliorating Huntington's disease as described herein wherein the kit comprises:

(i) a compound as described herein; and alternatively

(ii) an additional agent or therapy as described herein.

A kit as described herein may further include instructions for using the kit to treat, prevent, or ameliorate Huntington's disease as described herein by combination therapy as described herein.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein the linked nucleosides comprise at least 8, at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, at least 18, at least 19, or at least 20 contiguous nucleobases of a sequence recited in SEQ ID NO: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, or 36, for use in treating an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound so that expression of huntingtin is inhibited. In certain embodiments, the disease or condition is a neurological disorder. In certain embodiments, the disease or condition is Huntington's Disease. In certain embodiments, the animal is a human.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein the linked nucleosides comprise at least 8, at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, at least 18, at least 19, or at least 20 contiguous nucleobases of a sequence recited in SEQ ID NO: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, or 36, for use in an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound to prevent, treat, ameliorate, or slow progression of Huntington's disease.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein the linked nucleosides comprise at least 8, at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, at least 18, at least 19, or at least 20 contiguous nucleobases of a sequence recited in SEQ ID NO: 12, 22, 28, 30, 32, or 33, for use in an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound so that expression of huntingtin is inhibited. In certain embodiments, the disease or condition is a neurological disorder. In certain embodiments, the disease or condition is Huntington's Disease. In certain embodiments, the animal is a human.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12 to 30 linked nucleosides, wherein the linked nucleosides comprise at least 8, at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, at least 18, at least 19, or at least 20 contiguous nucleobases of a sequence recited in SEQ ID NO: 12, 22, 28, 30, 32, or 33, for use in an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound to prevent, treat, ameliorate, or slow progression of Huntington's disease.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12-30 linked nucleosides, wherein the linked nucleosides at least an 8, at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, at least a 14, at least a 15, at least a 16, at least a 17, at least a 18, at least a 19, or at least a 20 contiguous nucleobase portion complementary within the region selected from nucleotides 4384-4403, 4605-4624, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4617-4636, 4622-4639, 4813-4832, 4814-4833, 4823-4842, 4860-4877, 4868-4887, 4925-4944, 4928-4947, 4931-4950, 4931-4948, 4955-4974, 4960-4977, 5801-5820, 5809-5828, 5809-5826, 101088-101105, 115066-115085, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4813-4832, 4862-4881, 5809-5828 and 4928-4947 of SEQ ID NO: 1, for use in an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound so that expression of huntingtin is inhibited.

Certain embodiments provide compounds comprising a modified oligonucleotide consisting of 12-30 linked nucleosides, wherein the linked nucleosides comprise at least an 8, at least a 9, at least a 10, at least an 11, at least a 12, at least a 13, at least a 14, at least a 15, at least a 16, at least a 17, at least a 18, at least a 19, or at least a 20 contiguous nucleobase portion complementary within the region selected from nucleotides 4384-4403, 4605-4624, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4617-4636, 4622-4639, 4813-4832, 4814-4833, 4823-4842, 4860-4877, 4868-4887, 4925-4944, 4928-4947, 4931-4950, 4931-4948, 4955-4974, 4960-4977, 5801-5820, 5809-5828, 5809-5826, 101088-101105, 115066-115085, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4813-4832, 4862-4881, 5809-5828 and 4928-4947 of SEQ ID NO: 1, for use in an animal having a disease or condition associated with huntingtin by administering to the animal a therapeutically effective amount of the compound to prevent, treat, ameliorate, or slow progression of Huntington's disease.

Antisense Compounds

Oligomeric compounds include, but are not limited to, oligonucleotides, oligonucleosides, oligonucleotide analogs, oligonucleotide mimetics, antisense compounds, antisense oligonucleotides, and siRNAs. An oligomeric compound may be "antisense" to a target nucleic acid, meaning that is capable of undergoing hybridization to a target nucleic acid through hydrogen bonding.

In certain embodiments, an antisense compound has a nucleobase sequence that, when written in the 5' to 3' direction, comprises the reverse complement of the target segment of a target nucleic acid to which it is targeted. In certain such embodiments, an antisense oligonucleotide has a nucleobase sequence that, when written in the 5' to 3' direction, comprises the reverse complement of the target segment of a target nucleic acid to which it is targeted.

In certain embodiments, an antisense compound targeted to a huntingtin nucleic acid is 12 to 30 nucleotides in length. In other words, antisense compounds are from 12 to 30 linked nucleobases. In other embodiments, the antisense compound comprises a modified oligonucleotide consisting of 8 to 80, 12 to 50, 15 to 30, 18 to 24, 19 to 22, or 20 linked nucleobases.

In certain such embodiments, the antisense compound comprises a modified oligonucleotide consisting of 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, or 80 linked nucleobasis in length, or a range defined by any two of the above values.

In certain embodiments, the antisense compound comprises a shortened or truncated modified oligonucleotide. The shortened or truncated modified oligonucleotide can have a single nucleoside deleted from the 5' end (5' truncation), or alternatively from the 3' end β' truncation). A shortened or truncated oligonucleotide may have two nucleosides deleted from the 5' end, or alternatively may have two subunits deleted from the 3' end. Alternatively, the deleted nucleosides may be dispersed throughout the modified oligonucleotide, for example, in an antisense compound having one nucleoside deleted from the 5' end and one nucleoside deleted from the 3' end.

When a single additional nucleoside is present in a lengthened oligonucletide, the additional nucleoside may be located at the 5' or 3' end of the oligonucleotide. When two or more additional nucleosides are present, the added nucleosides may be adjacent to each other, for example, in an oligonucleotide having two nucleosides added to the 5' end (5' addition), or alternatively to the 3' end (3' addition), of the oligonucleotide. Alternatively, the added nucleoside may be dispersed throughout the antisense compound, for example, in an oligonucleotide having one nucleoside added to the 5' end and one subunit added to the 3' end.

It is possible to increase or decrease the length of an antisense compound, such as an antisense oligonucleotide, and/or introduce mismatch bases without eliminating activity. For example, in Woolf et al. (Proc. Natl. Acad. Sci. USA 89:7305-7309, 1992), a series of antisense oligonucleotides 13-25 nucleobases in length were tested for their ability to induce cleavage of a target RNA in an oocyte injection model. Antisense oligonucleotides 25 nucleobases in length with 8 or 11 mismatch bases near the ends of the antisense oligonucleotides were able to direct specific cleavage of the target mRNA, albeit to a lesser extent than the antisense oligonucleotides that contained no mismatches. Similarly, target specific cleavage was achieved using 13 nucleobase antisense oligonucleotides, including those with 1 or 3 mismatches.

Gautschi et al (J. Natl. Cancer Inst. 93:463-471, March 2001) demonstrated the ability of an oligonucleotide having 100% complementarity to the bcl-2 mRNA and having 3 mismatches to the bcl-xL mRNA to reduce the expression of both bcl-2 and bcl-xL in vitro and in vivo. Furthermore, this oligonucleotide demonstrated potent anti-tumor activity in vivo.

Maher and Dolnick (Nuc. Acid. Res. 16:3341-3358, 1988) tested a series of tandem 14 nucleobase antisense oligonucleotides, and a 28 and 42 nucleobase antisense oligonucleotides comprised of the sequence of two or three of the tandem antisense oligonucleotides, respectively, for their ability to arrest translation of human DHFR in a rabbit reticulocyte assay. Each of the three 14 nucleobase antisense oligonucleotides alone was able to inhibit translation, albeit at a more modest level than the 28 or 42 nucleobase antisense oligonucleotides.

Antisense Compound Motifs

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid have chemically modified subunits arranged in patterns, or motifs, to confer to the antisense compounds properties such as enhanced the inhibitory activity, increased binding affinity for a target nucleic acid, or resistance to degradation by in vivo nucleases.



Chimeric antisense compounds typically contain at least one region modified so as to confer increased resistance to nuclease degradation, increased cellular uptake, increased binding affinity for the target nucleic acid, and/or increased inhibitory activity. A second region of a chimeric antisense compound may optionally serve as a substrate for the cellular endonuclease RNase H, which cleaves the RNA strand of an RNA:DNA duplex.

Antisense compounds having a gapmer motif are considered chimeric antisense compounds. In a gapmer an internal region having a plurality of nucleotides that supports RNaseH cleavage is positioned between external regions having a plurality of nucleotides that are chemically distinct from the nucleosides of the internal region. In the case of an antisense oligonucleotide having a gapmer motif, the gap segment generally serves as the substrate for endonuclease cleavage, while the wing segments comprise modified nucleosides. In certain embodiments, the regions of a gapmer are differentiated by the types of sugar moieties comprising each distinct region. The types of sugar moieties that are used to differentiate the regions of a gapmer may in some embodiments include β-D-ribonucleosides, β-D-deoxyribonucleosides, 2'-modified nucleosides (such 2'-modified nucleosides may include 2'-MOE, and 2'-O—$CH_3$, among others), and bicyclic sugar modified nucleosides (such bicyclic sugar modified nucleosides may include those having a 4'-(CH2)n-O-2' bridge, where n=1 or n=2). Preferably, each distinct region comprises uniform sugar moieties. The wing-gap-wing motif is frequently described as "X-Y-Z", where "X" represents the length of the 5' wing region, "Y" represents the length of the gap region, and "Z" represents the length of the 3' wing region. As used herein, a gapmer described as "X-Y-Z" has a configuration such that the gap segment is positioned immediately adjacent each of the 5' wing segment and the 3' wing segment. Thus, no intervening nucleotides exist between the 5' wing segment and gap segment, or the gap segment and the 3' wing segment. Any of the antisense compounds described herein can have a gapmer motif. In some embodiments, X and Z are the same, in other embodiments they are different. In a preferred embodiment, Y is between 8 and 15 nucleotides. X, Y or Z can be any of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 25, 30 or more nucleotides. Thus, gapmers include, but are not limited to, for example 5-10-5, 4-8-4, 4-12-3, 4-12-4, 3-14-3, 2-13-5, 2-16-2, 1-18-1, 3-10-3, 2-10-2, 1-10-1, 2-8-2, 6-8-6 or 5-8-5.

In certain embodiments, the antisense compound as a "wingmer" motif, having a wing-gap or gap-wing configuration, i.e. an X-Y or Y-Z configuration as described above for the gapmer configuration. Thus, wingmer configurations include, but are not limited to, for example 5-10, 8-4, 4-12, 12-4, 3-14, 16-2, 18-1, 10-3, 2-10, 1-10, 8-2, 2-13, or 5-13.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid possess a 5-10-5 gapmer motif.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid possess a 6-8-6 gapmer motif.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid possess a 5-8-5 gapmer motif.

In certain embodiments, an antisense compound targeted to a huntingtin nucleic acid has a gap-widened motif.

In certain embodiments, a gap-widened antisense oligonucleotide targeted to a huntingtin nucleic acid has a gap segment often 2'-deoxyribonucleotides positioned immediately adjacent to and between wing segments of five chemically modified nucleosides. In certain embodiments, the chemical modification comprises a 2'-sugar modification. In another embodiment, the chemical modification comprises a 2'-MOE sugar modification.

In certain embodiments, a gap-widened antisense oligonucleotide targeted to a huntingtin nucleic acid has a gap segment of eight 2'-deoxyribonucleotides positioned immediately adjacent to and between wing segments of five chemically modified nucleosides. In certain embodiments, the chemical modification comprises a 2'-sugar modification. In another embodiment, the chemical modification comprises a 2'-MOE sugar modification.

In certain embodiments, a gap-widened antisense oligonucleotide targeted to a huntingtin nucleic acid has a gap segment of eight 2'-deoxyribonucleotides positioned immediately adjacent to and between wing segments of six chemically modified nucleosides. In certain embodiments, the chemical modification comprises a 2'-sugar modification. In another embodiment, the chemical modification comprises a 2'-MOE sugar modification.

Target Nucleic Acids, Target Regions and Nucleotide Sequences

Nucleotide sequences that encode huntingtin include, without limitation, the following: GENBANK Accession No. NM_002111.6, first deposited with GENBANK® on May 31, 2006 incorporated herein as SEQ ID NO: 1; GENBANK Accession No. NT_006081.17 truncated from nucleotides 462000 to 634000, first deposited with GENBANK® on Aug. 19, 2004, and incorporated herein as SEQ ID NO: 2; GENBANK Accession No. NM_010414.1, first deposited with GENBANK® on Mar. 23, 2004, incorporated herein as SEQ ID NO: 3; the complement of GENBANK Accession No. NW_001109716.1 truncated at nucleotides 698000 to 866000, first deposited with GENBANK® on Jun. 14, 2006, incorporated herein as SEQ ID NO: 4, and GENBANK Accession No. NM_024357.2, first deposited with GENBANK® on Jun. 5, 2008, incorporated herein as SEQ ID NO: 5.

It is understood that the sequence set forth in each SEQ ID NO in the Examples contained herein is independent of any modification to a sugar moiety, an internucleoside linkage, or a nucleobase. As such, antisense compounds defined by a SEQ ID NO may comprise, independently, one or more modifications to a sugar moiety, an internucleoside linkage, or a nucleobase. Antisense compounds described by Isis Number (Isis No) indicate a combination of nucleobase sequence and motif.

In certain embodiments, a target region is a structurally defined region of the target nucleic acid. For example, a target region may encompass a 3' UTR, a 5' UTR, an exon, an intron, an exon/intron junction, a coding region, a translation initiation region, translation termination region, or other defined nucleic acid region. The structurally defined regions for huntingtin can be obtained by accession number from sequence databases such as NCBI and such information is incorporated herein by reference. In certain embodiments, a target region may encompass the sequence from a 5' target site of one target segment within the target region to a 3' target site of another target segment within the target region.

Targeting includes determination of at least one target segment to which an antisense compound hybridizes, such that a desired effect occurs. In certain embodiments, the desired effect is a reduction in mRNA target nucleic acid levels. In certain embodiments, the desired effect is reduction of levels of protein encoded by the target nucleic acid or a phenotypic change associated with the target nucleic acid.

A target region may contain one or more target segments. Multiple target segments within a target region may be overlapping. Alternatively, they may be non-overlapping. In certain embodiments, target segments within a target region are separated by no more than about 300 nucleotides. In certain embodiments, target segments within a target region are separated by a number of nucleotides that is, is about, is no more than, is no more than about, 250, 200, 150, 100, 90, 80, 70, 60, 50, 40, 30, 20, or 10 nucleotides on the target nucleic acid, or is a range defined by any two of the preceding values. In certain embodiments, target segments within a target region are separated by no more than, or no more than about, 5 nucleotides on the target nucleic acid. In certain embodiments, target segments are contiguous. Contemplated are target regions defined by a range having a starting nucleic acid that is any of the 5' target sites or 3' target sites listed herein.

Suitable target segments may be found within a 5' UTR, a coding region, a 3' UTR, an intron, an exon, or an exon/intron junction. Target segments containing a start codon or a stop codon are also suitable target segments. A suitable target segment may specifically exclude a certain structurally defined region such as the start codon or stop codon.

The determination of suitable target segments may include a comparison of the sequence of a target nucleic acid to other sequences throughout the genome. For example, the BLAST algorithm may be used to identify regions of similarity amongst different nucleic acids. This comparison can prevent the selection of antisense compound sequences that may hybridize in a non-specific manner to sequences other than a selected target nucleic acid (i.e., non-target or off-target sequences).

There may be variation in activity (e.g., as defined by percent reduction of target nucleic acid levels) of the antisense compounds within an active target region. In certain embodiments, reductions in huntingtin mRNA levels are indicative of inhibition of huntingtin expression. Reductions in levels of a huntingtin protein are also indicative of inhibition of target mRNA expression. Further, phenotypic changes are indicative of inhibition of huntingtin expression. For example, increase in brain size to normal, improvement in motor coordination, decrease in continual muscular spasms (dystonia), decrease in irritability and/or anxiety, improvement of memory, or an increase in energy, among other phenotypic changes that may be assayed. Other phenotypic indications, e.g., symptoms associated with Huntington's disease, may also be assessed as described below.

Hybridization

In some embodiments, hybridization occurs between an antisense compound disclosed herein and a huntingtin nucleic acid. The most common mechanism of hybridization involves hydrogen bonding (e.g., Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding) between complementary nucleobases of the nucleic acid molecules.

Hybridization can occur under varying conditions. Stringent conditions are sequence-dependent and are determined by the nature and composition of the nucleic acid molecules to be hybridized.

Methods of determining whether a sequence is specifically hybridizable to a target nucleic acid are well known in the art. In certain embodiments, the antisense compounds provided herein are specifically hybridizable with a huntingtin nucleic acid.

Complementarity

An antisense compound and a target nucleic acid are complementary to each other when a sufficient number of nucleobases of the antisense compound can hydrogen bond with the corresponding nucleobases of the target nucleic acid, such that a desired effect will occur (e.g., antisense inhibition of a target nucleic acid, such as a huntingtin nucleic acid).

An antisense compound may hybridize over one or more segments of a huntingtin nucleic acid such that intervening or adjacent segments are not involved in the hybridization event (e.g., a loop structure, mismatch or hairpin structure).

In certain embodiments, the antisense compounds provided herein, or a specified portion thereof, are, or are at least, 70%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% complementary to a huntingtin nucleic acid, a target region, target segment, or specified portion thereof. Percent complementarity of an antisense compound with a target nucleic acid can be determined using routine methods.

For example, an antisense compound in which 18 of 20 nucleobases of the antisense compound are complementary to a target region, and would therefore specifically hybridize, would represent 90 percent complementarity. In this example, the remaining noncomplementary nucleobases may be clustered or interspersed with complementary nucleobases and need not be contiguous to each other or to complementary nucleobases. As such, an antisense compound which is 18 nucleobases in length having 4 (four) noncomplementary nucleobases which are flanked by two regions of complete complementarity with the target nucleic acid would have 77.8% overall complementarity with the target nucleic acid and would thus fall within the scope of the present invention. Percent complementarity of an antisense compound with a region of a target nucleic acid can be determined routinely using BLAST programs (basic local alignment search tools) and PowerBLAST programs known in the art (Altschul et al., J. Mol. Biol., 1990, 215, 403 410; Zhang and Madden, Genome Res., 1997, 7, 649 656). Percent homology, sequence identity or complementarity, can be determined by, for example, the Gap program (Wisconsin Sequence Analysis Package, Version 8 for Unix, Genetics Computer Group, University Research Park, Madison Wis.), using default settings, which uses the algorithm of Smith and Waterman (Adv. Appl. Math., 1981, 2, 482 489).

In certain embodiments, the antisense compounds provided herein, or specified portions thereof, are fully complementary (i.e. 100% complementary) to a target nucleic acid, or specified portion thereof. For example, antisense compound may be fully complementary to a huntingtin nucleic acid, or a target region, or a target segment or target sequence thereof. As used herein, "fully complementary" means each nucleobase of an antisense compound is capable of precise base pairing with the corresponding nucleobases of a target nucleic acid. For example, a 20 nucleobase antisense compound is fully complementary to a target sequence that is 400 nucleobases long, so long as there is a corresponding 20 nucleobase portion of the target nucleic acid that is fully complementary to the antisense compound. Fully complementary can also be used in reference to a specified portion of the first and/or the second nucleic acid. For example, a 20 nucleobase portion of a 30 nucleobase antisense compound can be "fully complementary" to a target sequence that is 400 nucleobases long. The 20 nucleobase portion of the 30 nucleobase oligonucleotide is fully complementary to the target sequence if the target sequence has a corresponding 20 nucleobase portion wherein each nucleobase is complementary to the 20 nucleobase portion of the antisense compound. At the same time, the entire 30 nucleobase antisense compound may or may not be fully complementary to the target sequence, depending on whether the remaining 10 nucleobases of the antisense compound are also complementary to the target sequence.

The location of a non-complementary nucleobase may be at the 5' end or 3' end of the antisense compound. Alternatively, the non-complementary nucleobase or nucleobases may be at an internal position of the antisense compound. When two or more non-complementary nucleobases are present, they may be contiguous (i.e. linked) or non-contiguous. In one embodiment, a non-complementary nucleobase is located in the wing segment of a gapmer antisense oligonucleotide.

In certain embodiments, antisense compounds that are, or are up to 12, 13, 14, 15, 16, 17, 18, 19, or 20 nucleobases in length comprise no more than 4, no more than 3, no more than 2, or no more than 1 non-complementary nucleobase(s) relative to a target nucleic acid, such as a huntingtin nucleic acid, or specified portion thereof.

In certain embodiments, antisense compounds that are, or are up to 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, or 30 nucleobases in length comprise no more than 6, no more than 5, no more than 4, no more than 3, no more than 2, or no more than 1 non-complementary nucleobase(s) relative to a target nucleic acid, such as a huntingtin nucleic acid, or specified portion thereof.

The antisense compounds provided herein also include those which are complementary to a portion of a target nucleic acid. As used herein, "portion" refers to a defined number of contiguous (i.e. linked) nucleobases within a region or segment of a target nucleic acid. A "portion" can also refer to a defined number of contiguous nucleobases of an antisense compound. In certain embodiments, the antisense compounds, are complementary to at least an 8 nucleobase portion of a target segment. In certain embodiments, the antisense compounds are complementary to at least a 12 nucleobase portion of a target segment. In certain embodiments, the antisense compounds are complementary to at least a 15 nucleobase portion of a target segment. Also contemplated are antisense compounds that are complementary to at least a 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or more nucleobase portion of a target segment, or a range defined by any two of these values.

Identity

The antisense compounds provided herein may also have a defined percent identity to a particular nucleotide sequence, SEQ ID NO, or compound represented by a specific Isis number, or portion thereof. As used herein, an antisense compound is identical to the sequence disclosed herein if it has the same nucleobase pairing ability. For example, a RNA which contains uracil in place of thymidine in a disclosed DNA sequence would be considered identical to the DNA sequence since both uracil and thymidine pair with adenine. Shortened and lengthened versions of the antisense compounds described herein as well as compounds having non-identical bases relative to the antisense compounds provided herein also are contemplated. The non-identical bases may be adjacent to each other or dispersed throughout the antisense compound. Percent identity of an antisense compound is calculated according to the number of bases that have identical base pairing relative to the sequence to which it is being compared.

In certain embodiments, the antisense compounds, or portions thereof, are at least 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to one or more of the antisense compounds or SEQ ID NOs, or a portion thereof, disclosed herein.

Modifications

A nucleoside is a base-sugar combination. The nucleobase (also known as base) portion of the nucleoside is normally a heterocyclic base moiety. Nucleotides are nucleosides that further include a phosphate group covalently linked to the sugar portion of the nucleoside. For those nucleosides that include a pentofuranosyl sugar, the phosphate group can be linked to the 2', 3' or 5' hydroxyl moiety of the sugar. Oligonucleotides are formed through the covalent linkage of adjacent nucleosides to one another, to form a linear polymeric oligonucleotide. Within the oligonucleotide structure, the phosphate groups are commonly referred to as forming the internucleoside linkages of the oligonucleotide.

Modifications to antisense compounds encompass substitutions or changes to internucleoside linkages, sugar moieties, or nucleobases. Modified antisense compounds are often preferred over native forms because of desirable properties such as, for example, enhanced cellular uptake, enhanced affinity for nucleic acid target, increased stability in the presence of nucleases, or increased inhibitory activity.

Chemically modified nucleosides may also be employed to increase the binding affinity of a shortened or truncated antisense oligonucleotide for its target nucleic acid. Consequently, comparable results can often be obtained with shorter antisense compounds that have such chemically modified nucleosides.

Modified Internucleoside Linkages

The naturally occurring internucleoside linkage of RNA and DNA is a 3' to 5' phosphodiester linkage. Antisense compounds having one or more modified, i.e. non-naturally occurring, internucleoside linkages are often selected over antisense compounds having naturally occurring internucleoside linkages because of desirable properties such as, for example, enhanced cellular uptake, enhanced affinity for target nucleic acids, and increased stability in the presence of nucleases.

Oligonucleotides having modified internucleoside linkages include internucleoside linkages that retain a phosphorus atom as well as internucleoside linkages that do not have a phosphorus atom. Representative phosphorus containing internucleoside linkages include, but are not limited to, phosphodiesters, phosphotriesters, methylphosphonates, phosphoramidate, and phosphorothioates. Methods of preparation of phosphorous-containing and non-phosphorous-containing linkages are well known.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid comprise one or more modified internucleoside linkages. In certain embodiments, the modified internucleoside linkages are phosphorothioate linkages. In certain embodiments, each internucleoside linkage of an antisense compound is a phosphorothioate internucleoside linkage.

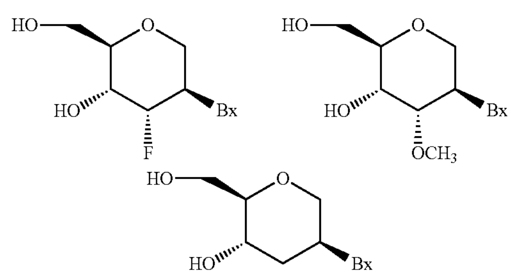
Modified Sugar Moieties

Antisense compounds can optionally contain one or more nucleosides wherein the sugar group has been modified. Such sugar modified nucleosides may impart enhanced nuclease stability, increased binding affinity or some other beneficial biological property to the antisense compounds. In certain embodiments, nucleosides comprise a chemically modified ribofuranose ring moieties. Examples of chemically modified ribofuranose rings include without limitation, addition of substitutent groups (including 5' and 2' substituent groups, bridging of non-geminal ring atoms to form bicyclic nucleic acids (BNA), replacement of the ribosyl ring oxygen atom with S, N(R), or C(R1)(R)2 (R=H, C1-C12 alkyl or a protecting group) and combinations thereof. Examples of chemically modified sugars include 2'-F-5'-methyl substituted nucleoside (see PCT International Application WO 2008/101157 Published on Aug. 21, 2008 for other disclosed 5',2'-bis substituted nucleosides) or replacement of the ribosyl ring oxygen atom with S with further substitution at the 2'-position (see published U.S. Patent Application US2005-0130923, published on Jun. 16, 2005) or alternatively 5'-substitution of a BNA (see PCT International Application WO 2007/134181 Published on Nov. 22, 2007 wherein LNA is substituted with for example a 5'-methyl or a 5'-vinyl group).

Examples of nucleosides having modified sugar moieties include without limitation nucleosides comprising 5'-vinyl, 5'-methyl (R or S), 4'-S, 2'-F, 2'-OCH3 and 2'-O(CH2)2OCH3 substituent groups. The substituent at the 2' position can also be selected from allyl, amino, azido, thio, O-allyl, O—C1-C10 alkyl, OCF3, O(CH2)2SCH3, O(CH2)2-O—N(Rm)(Rn), and O—CH2-C(=O)—N(Rm)(Rn), where each Rm and Rn is, independently, H or substituted or unsubstituted C1-C10 alkyl.

Examples of bicyclic nucleic acids (BNAs) include without limitation nucleosides comprising a bridge between the 4' and the 2' ribosyl ring atoms. In certain embodiments, antisense compounds provided herein include one or more BNA nucleosides wherein the bridge comprises one of the formulas: 4'-(CH2)-O-2' (LNA); 4'-(CH2)-S-2; 4'-(CH2)-O-2' (LNA); 4'-(CH2)2-O-2' (ENA); 4'-C(CH3)2-O-2' (see PCT/US2008/068922); 4'-CH(CH3)-O-2' and 4'-C—H(CH2OCH3)-O-2' (see U.S. Pat. No. 7,399,845, issued on Jul. 15, 2008); 4'-CH2-N(OCH3)-2' (see PCT/US2008/064591); 4'-CH2-O—N(CH3)-2' (see published U.S. Patent Application US2004-0171570, published Sep. 2, 2004); 4'-CH2-N(R)—O-2' (see U.S. Pat. No. 7,427,672, issued on Sep. 23, 2008); 4'-CH2-C(CH3)-2' and 4'-CH2-C-(=CH2)-2' (see PCT/US2008/066154); and wherein R is, independently, H, C1-C12 alkyl, or a protecting group. Each of the foregoing BNAs include various stereochemical sugar configurations including for example α-L-ribofuranose and β-D-ribofuranose (see PCT international application PCT/DK98/00393, published on Mar. 25, 1999 as WO 99/14226).

In certain embodiments, nucleosides are modified by replacement of the ribosyl ring with a sugar surrogate. Such modification includes without limitation, replacement of the ribosyl ring with a surrogate ring system (sometimes referred to as DNA analogs) such as a morpholino ring, a cyclohexenyl ring, a cyclohexyl ring or a tetrahydropyranyl ring such as one having one of the formula:



Many other bicyclo and tricyclo sugar surrogate ring systems are also known in the art that can be used to modify nucleosides for incorporation into antisense compounds (see, e.g., review article: Leumann, J. C, *Bioorganic & Medicinal Chemistry,* 2002, 10, 841-854). Such ring systems can undergo various additional substitutions to enhance activity.

Methods for the preparations of modified sugars are well known to those skilled in the art.

In nucleotides having modified sugar moieties, the nucleobase moieties (natural, modified or a combination thereof) are maintained for hybridization with an appropriate nucleic acid target.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid comprise one or more nucleotides having modified sugar moieties. In certain embodiments, the modified sugar moiety is 2'-MOE. In certain embodiments, the 2'-MOE modified nucleotides are arranged in a gapmer motif.

Modified Nucleobases

Nucleobase (or base) modifications or substitutions are structurally distinguishable from, yet functionally interchangeable with, naturally occurring or synthetic unmodified nucleobases. Both natural and modified nucleobases are capable of participating in hydrogen bonding. Such nucleobase modifications may impart nuclease stability, binding affinity or some other beneficial biological property to antisense compounds. Modified nucleobases include synthetic and natural nucleobases such as, for example, 5-methylcytosine (5-me-C). Certain nucleobase substitutions, including 5-methylcytosine substitutions, are particularly useful for increasing the binding affinity of an antisense compound for a target nucleic acid. For example, 5-methylcytosine substitutions have been shown to increase nucleic acid duplex stability by 0.6-1.2° C. (Sanghvi, Y. S., Crooke, S. T. and Lebleu, B., eds., *Antisense Research and Applications*, CRC Press, Boca Raton, 1993, pp. 276-278).

Additional unmodified nucleobases include 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-halouracil and cytosine, 5-propynyl ($-C\equiv C-CH_3$) uracil and cytosine and other alkynyl derivatives of pyrimidine bases, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxyl and other 8-substituted adenines and guanines, 5-halo particularly 5-bromo, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine and 7-methyladenine, 2-F-adenine, 2-amino-adenine, 8-azaguanine and 8-azaadenine, 7-deazaguanine and 7-deazaadenine and 3-deazaguanine and 3-deazaadenine.

Heterocyclic base moieties may also include those in which the purine or pyrimidine base is replaced with other heterocycles, for example 7-deaza-adenine, 7-deazaguanosine, 2-aminopyridine and 2-pyridone. Nucleobases that are particularly useful for increasing the binding affinity of antisense compounds include 5-substituted pyrimidines, 6-azapyrimidines and N-2, N-6 and 0-6 substituted purines, including 2 aminopropyladenine, 5-propynyluracil and 5-propynylcytosine.

In certain embodiments, antisense compounds targeted to a huntingtin nucleic acid comprise one or more modified nucleobases. In certain embodiments, gap-widened antisense oligonucleotides targeted to a huntingtin nucleic acid comprise one or more modified nucleobases. In certain embodiments, the modified nucleobase is 5-methylcytosine. In certain embodiments, each cytosine is a 5-methylcytosine.

Compositions and Methods for Formulating Pharmaceutical Compositions

Antisense oligonucleotides may be admixed with pharmaceutically acceptable active or inert substance for the preparation of pharmaceutical compositions or formulations. Compositions and methods for the formulation of pharmaceutical compositions are dependent upon a number of criteria, including, but not limited to, route of administration, extent of disease, or dose to be administered.

Antisense compound targeted to a huntingtin nucleic acid can be utilized in pharmaceutical compositions by combining the antisense compound with a suitable pharmaceutically acceptable diluent or carrier. A pharmaceutically acceptable diluent includes phosphate-buffered saline (PBS). PBS is a diluent suitable for use in compositions to be delivered parenterally. Accordingly, in one embodiment, employed in the methods described herein is a pharmaceutical composition comprising an antisense compound targeted to a huntingtin nucleic acid and a pharmaceutically acceptable diluent. In certain embodiments, the pharmaceutically acceptable diluent is PBS. In certain embodiments, the antisense compound is an antisense oligonucleotide.

Pharmaceutical compositions comprising antisense compounds encompass any pharmaceutically acceptable salts, esters, or salts of such esters, or any other oligonucleotide which, upon administration to an animal, including a human, is capable of providing (directly or indirectly) the biologically active metabolite or residue thereof. Accordingly, for example, the disclosure is also drawn to pharmaceutically acceptable salts of antisense compounds, prodrugs, pharmaceutically acceptable salts of such prodrugs, and other bioequivalents. Suitable pharmaceutically acceptable salts include, but are not limited to, sodium and potassium salts.

A prodrug can include the incorporation of additional nucleosides at one or both ends of an antisense compound which are cleaved by endogenous nucleases within the body, to form the active antisense compound.

Conjugated Antisense Compounds

Antisense compounds may be covalently linked to one or more moieties or conjugates which enhance the activity, cellular distribution or cellular uptake of the resulting antisense oligonucleotides. Typical conjugate groups include cholesterol moieties and lipid moieties. Additional conjugate groups include carbohydrates, phospholipids, biotin, phenazine, folate, phenanthridine, anthraquinone, acridine, fluoresceins, rhodamines, coumarins, and dyes.

Antisense compounds can also be modified to have one or more stabilizing groups that are generally attached to one or both termini of antisense compounds to enhance properties such as, for example, nuclease stability. Included in stabilizing groups are cap structures. These terminal modifications protect the antisense compound having terminal nucleic acid from exonuclease degradation, and can help in delivery and/or localization within a cell. The cap can be present at the 5'-terminus (5'-cap), or at the 3'-terminus β'-cap), or can be present on both termini. Cap structures are well known in the art and include, for example, inverted deoxy abasic caps. Further 3' and 5'-stabilizing groups that can be used to cap one or both ends of an antisense compound to impart nuclease stability include those disclosed in WO 03/004602 published on Jan. 16, 2003.

Cell Culture and Antisense Compounds Treatment

The effects of antisense compounds on the level, activity or expression of huntingtin nucleic acids can be tested in vitro in a variety of cell types. Cell types used for such analyses are available from commercial vendors (e.g. American Type Culture Collection, Manassas, Va.; Zen-Bio, Inc., Research Triangle Park, N.C.; Clonetics Corporation, Walkersville, Md.) and cells are cultured according to the vendor's instructions using commercially available reagents (e.g. Invitrogen Life Technologies, Carlsbad, Calif.). Illustrative cell types include, but are not limited to, HepG2 cells, Hep3B cells, primary hepatocytes, A549 cells, GM04281 fibroblasts and LLC-MK2 cells.

In Vitro Testing of Antisense Oligonucleotides

Described herein are methods for treatment of cells with antisense oligonucleotides, which can be modified appropriately for treatment with other antisense compounds.

In general, cells are treated with antisense oligonucleotides when the cells reach approximately 60-80% confluence in culture.

One reagent commonly used to introduce antisense oligonucleotides into cultured cells includes the cationic lipid transfection reagent LIPOFECTIN® (Invitrogen, Carlsbad, Calif.). Antisense oligonucleotides are mixed with LIPOFECTIN® in OPTI-MEM® 1 (Invitrogen, Carlsbad, Calif.) to achieve the desired final concentration of antisense oligonucleotide and a LIPOFECTIN® concentration that typically ranges 2 to 12 ug/mL per 100 nM antisense oligonucleotide.

Another reagent used to introduce antisense oligonucleotides into cultured cells includes LIPOFECTAMINE 2000® (Invitrogen, Carlsbad, Calif.). Antisense oligonucleotide is mixed with LIPOFECTAMINE 2000® in OPTI-MEM® 1 reduced serum medium (Invitrogen, Carlsbad, Calif.) to achieve the desired concentration of antisense oligonucleotide and a LIPOFECTAMINE® concentration that typically ranges 2 to 12 ug/mL per 100 nM antisense oligonucleotide.

Another reagent used to introduce antisense oligonucleotides into cultured cells includes Cytofectin® (Invitrogen, Carlsbad, Calif.). Antisense oligonucleotide is mixed with Cytofectin® in OPTI-MEM® 1 reduced serum medium (Invitrogen, Carlsbad, Calif.) to achieve the desired concentration of antisense oligonucleotide and a Cytofectin® concentration that typically ranges 2 to 12 ug/mL per 100 nM antisense oligonucleotide.

Another technique used to introduce antisense oligonucleotides into cultured cells includes electroporation.

Cells are treated with antisense oligonucleotides by routine methods. Cells are typically harvested 16-24 hours after antisense oligonucleotide treatment, at which time RNA or protein levels of target nucleic acids are measured by methods known in the art and described herein. In general, when treatments are performed in multiple replicates, the data are presented as the average of the replicate treatments.

The concentration of antisense oligonucleotide used varies from cell line to cell line. Methods to determine the optimal antisense oligonucleotide concentration for a particular cell line are well known in the art. Antisense oligonucleotides are typically used at concentrations ranging from 1 nM to 300 nM when transfected with LIPOFECTAMINE2000®, Lipofectin or Cytofectin. Antisense oligonucleotides are used at higher concentrations ranging from 625 to 20,000 nM when transfected using electroporation.

RNA Isolation

RNA analysis can be performed on total cellular RNA or poly(A)+mRNA. Methods of RNA isolation are well known in the art. RNA is prepared using methods well known in the art, for example, using the TRIZOL® Reagent (Invitrogen, Carlsbad, Calif.) according to the manufacturer's recommended protocols.

Analysis of Inhibition of Target Levels or Expression

Inhibition of levels or expression of a huntingtin nucleic acid can be assayed in a variety of ways known in the art. For example, target nucleic acid levels can be quantitated by, e.g., Northern blot analysis, competitive polymerase chain reaction (PCR), or quantitaive real-time PCR. RNA analysis can be performed on total cellular RNA or poly(A)+ mRNA. Methods of RNA isolation are well known in the art. Northern blot analysis is also routine in the art. Quantitative real-time PCR can be conveniently accomplished using the commercially available ABI PRISM® 7600, 7700, or 7900 Sequence Detection System, available from PE-Applied Biosystems, Foster City, Calif. and used according to manufacturer's instructions.

Quantitative Real-Time PCR Analysis of Target RNA Levels

Quantitation of target RNA levels may be accomplished by quantitative real-time PCR using the ABI PRISM® 7600, 7700, or 7900 Sequence Detection System (PE-Applied Biosystems, Foster City, Calif.) according to manufacturer's instructions. Methods of quantitative real-time PCR are well known in the art.

Prior to real-time PCR, the isolated RNA is subjected to a reverse transcriptase (RT) reaction, which produces complementary DNA (cDNA) that is then used as the substrate for the real-time PCR amplification. The RT and real-time PCR reactions are performed sequentially in the same sample well. RT and real-time PCR reagents are obtained from Invitrogen (Carlsbad, Calif.). RT, real-time-PCR reactions are carried out by methods well known to those skilled in the art.

Gene (or RNA) target quantities obtained by real time PCR are normalized using either the expression level of a gene whose expression is constant, such as cyclophilin A, or by quantifying total RNA using RIBOGREEN® (Invitrogen, Inc. Carlsbad, Calif.). Cyclophilin A expression is quantified by real time PCR, by being run simultaneously with the target, multiplexing, or separately. Total RNA is quantified using RIBOGREEN® RNA quantification reagent (Invitrogen, Inc. Eugene, Oreg.). Methods of RNA quantification by RIBOGREEN® are taught in Jones, L. J., et al, (Analytical Biochemistry, 1998, 265, 368-374). A CYTOFLUOR® 4000 instrument (PE Applied Biosystems) is used to measure RIBOGREEN® fluorescence.

Probes and primers are designed to hybridize to a huntingtin nucleic acid. Methods for designing real-time PCR probes and primers are well known in the art, and may include the use of software such as PRIMER EXPRESS® Software (Applied Biosystems, Foster City, Calif.).

Analysis of Protein Levels

Antisense inhibition of huntingtin nucleic acids can be assessed by measuring huntingtin protein levels. Protein levels of huntingtin can be evaluated or quantitated in a variety of ways well known in the art, such as immunoprecipitation, Western blot analysis (immunoblotting), enzyme-linked immunosorbent assay (ELISA), quantitative protein assays, protein activity assays (for example, caspase activity assays), immunohistochemistry, immunocytochemistry or fluorescence-activated cell sorting (FACS). Antibodies directed to a target can be identified and obtained from a variety of sources, such as the MSRS catalog of antibodies (Aerie Corporation, Birmingham, Mich.), or can be prepared via conventional monoclonal or polyclonal antibody generation methods well known in the art. Antibodies useful for the detection of human and rat huntingtin are commercially available.

In Vivo Testing of Antisense Compounds

Antisense compounds, for example, antisense oligonucleotides, are tested in animals to assess their ability to inhibit expression of huntingtin and produce phenotypic changes. Testing may be performed in normal animals, or in experimental disease models. For administration to animals, antisense oligonucleotides are formulated in a pharmaceutically acceptable diluent, such as phosphate-buffered saline. Administration includes parenteral routes of administration. Following a period of treatment with antisense oligonucleotides, RNA is isolated from tissue and changes in huntingtin nucleic acid expression are measured. Changes in huntingtin protein levels are also measured.

Certain Compounds

About seventeen hundred newly designed antisense compounds of various lengths, motifs and backbone composition were tested for their effect on human huntingtin mRNA in vitro in several cell types. The new compounds were compared with about two hundred and fifty previously designed compounds including ISIS 387916 which had previously been determined to be one of the most potent antisense compounds in vitro (see e.g., U.S. Patent Publication Nos. 2008/

0039418 and 2007/0299027. Of the about seventeen hundred newly designed antisense compounds, about sixty compounds were selected for further study based on in vitro potency compared to ISIS 387916. The selected compounds were tested for systemic tolerability (see Example 3) and activity and tolerability in the brain of BACHD mice (see Example 4) compared to previously designed ISIS 388241 and ISIS 387916. From these studies, compounds having a nucleobase sequence of a sequence recited in SEQ ID NO: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22 or 32 were selected as having high tolerability and high in vivo potency. By virtue of their complementary sequence, the compounds are complementary to the regions 4384-4403, 4605-4624, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4617-4636, 4622-4639, 4813-4832, 4814-4833, 4823-4842, 4860-4877, 4868-4887, 4925-4944, 4928-4947, 4931-4950, 4931-4948, 4955-4974, 4960-4977, 5801-5820, 5809-5828, 5809-5826, 101088-101105, 115066-115085, 4607-4626, 4608-4627, 4609-4628, 4610-4629, 4813-4832, 4862-4881, 5809-5828 or 4928-4947 of SEQ ID NO: 1. In certain embodiments, the compounds targeting the listed regions, as further described herein, comprise a modified oligonucleotide having some nucleobase portion of the sequence recited in the SEQ ID NOs, as further described herein. In certain embodiments, the compounds targeting the listed regions or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs can be of various length, as further described herein, and can have one of various motifs, as further described herein. In certain embodiments, a compound targeting a region or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs has the specific length and motif as indicated by the ISIS NOs: ISIS 419628, ISIS 419637, ISIS 419640, ISIS 419641, ISIS 451541, ISIS 419642, ISIS 436665, ISIS 436671, ISIS 436684, ISIS 436689, ISIS 436754, ISIS 437168, ISIS 437175, ISIS 437441, ISIS 437442, ISIS 437507, ISIS 437527, ISIS 443139, ISIS 444578, ISIS 444584, ISIS 444591, ISIS 444607, ISIS 444608, ISIS 444615, ISIS 444618, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, ISIS 444661, or ISIS 444663.

Compounds described above as having high in vivo potency and tolerability were then tested by CNS bolus injection in rat to further assess neurotoxicity (see Example 5) along with several additional compounds having a nucleobase sequence of a sequence recited in SEQ ID NO: 7, 8, 11, 16, 17. Of these, ten compounds having a nucleobase sequence of a sequence recited in SEQ ID NO: 24, 25, 26, 6, 12, 28, 21, 22, 32 or 13 were selected as having high tolerability. By virtue of their complementary sequence, the compounds are complementary to the regions 4384-4403, 4609-4628, 4610-4629, 4860-4877, 4862-4881, 4925-4944, 4928-4947, 4931-4950, 4955-4974, or 5809-5829 of SEQ ID NO: 1. In certain embodiments, the compounds targeting the listed regions, as further described herein, comprise a modified oligonucleotide having some nucleobase portion of the sequence recited in the SEQ ID NOs, as further described herein. In certain embodiments, the compounds targeting the listed regions or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs can be of various length, as further described herein, and can have one of various motifs, as further described herein. In certain embodiments, a compound targeting a region or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs has the specific length and motif as indicated by the ISIS NOs: ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436671, ISIS 436689, ISIS 437507, ISIS 443139, ISIS 444591, and ISIS 444661. Selected compounds were compared with previously designed compound ISIS 388241 by ICV administration in BACHD mice.

Additional studies were then run on compounds described above as having high in vivo potency and tolerability. The additional studies were designed to further assess neurotoxicity. Studies included ICV administration in wild-type mouse (see Example 16) and bolus administration in rat (see Example 17). SEQ ID NOs: 12, 22, 28, 30, 32, and 33 were selected as having high neurotolerability. By virtue of their complementary sequence, the compounds are complementary to the regions 4862-4881, 4609-4628, 5809-5828, 5809-5826, 5801-5820, and 4955-4974 of SEQ ID NO: 1. In certain embodiments, the compounds targeting the listed regions, as further described herein, comprise a modified oligonucleotide having some nucleobase portion of the sequence recited in the SEQ ID NOs, as further described herein. In certain embodiments, the compounds targeting the listed regions or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs can be of various length, as further described herein, and can have one of various motifs, as further described herein. In certain embodiments, a compound targeting a region or having a nucleobase portion of a sequence recited in the listed SEQ ID NOs has the specific length and motif as indicated by ISIS 388241, ISIS 443139, ISIS 436671, ISIS 444591, ISIS 437527, ISIS 444584, ISIS 444652, and ISIS 436689.

Accordingly, provided herein are antisense compounds with improved characteristics. In certain embodiments, provided herein are compounds comprising a modified oligonucleotide as further described herein targeted to or specifically hybridizable with the region of nucleotides of SEQ ID NO: 1.

In certain embodiments, the compounds as described herein are efficacious by virtue of having at least one of an in vitro IC50 of less than 7 uM, less than 6 uM, less than 5, uM, less than 4 uM, less than 3 uM, less than 2 uM, less than 1 uM when delivered to a human fibroblast cell line as described herein or an ED50 of less than 10 μg, less than 9 μg, less than 8 μg, less than 7.5 μg, less than 7.4 μg, less than 7.0 μg, less than 6 μg, less than 5 μg, less than 4 μg, less than 3 μg, or less than 2 μg by bolus injection. As described herein, ICV infusion can result in 3 to 4 fold higher ED50 values for the compounds described herein. In certain embodiments, the compounds as described herein are highly tolerable as demonstrated by having at least one of an increase an ALT or AST value of no more than 4 fold, 3 fold, or 2 fold over saline treated animals; an increase in liver, spleen or kidney weight of no more than 30%, 20%, 15%, 12%, 10%, 5% or 2%; or an increase AIF1 levels by no more than 350%, 300%, 275%, 250% 200%, 150% or 100% over control.

Certain Indications

In certain embodiments, provided herein are methods of treating an individual comprising administering one or more pharmaceutical compositions as described herein. In certain embodiments, the individual has Huntington's disease.

As shown in the examples below, compounds targeted to huntingtin as described herein have been shown to reduce the severity of physiological symptoms of Huntington's disease. In certain of the experiments, the compounds reduced rate of degeneration, e.g., the animals continued to experience symptoms, but the symptoms were less severe compared to untreated animals. In other of the experiments, however, the compounds appear to result in regeneration of function over time; e.g., animals treated for a longer period of time experienced less severe symptoms than those administered the compounds for a shorter period of time. As discussed above, Huntington's disease is a degenerative disease with a progression typified by increased severity of symptoms over time. The ability of the compounds exemplified below to restore function therefore demonstrates that symptoms of the disease may be reversed by treatment with a compound as described herein.

Accordingly, provided herein are methods for ameliorating a symptom associated with Huntington's disease in a subject in need thereof. In certain embodiments, provided is a method for reducing the rate of onset of a symptom associated with Huntington's disease. In certain embodiments, provided is a method for reducing the severity of a symptom associated with Huntington's disease. In certain embodiments, provided is a method for regenerating neurological function as shown by an improvement of a symptom associated with Huntington's disease. In such embodiments, the methods comprise administering to an individual in need thereof a therapeutically effective amount of a compound targeted to a huntingtin nucleic acid.

Huntington's disease is characterized by numerous physical, neurological, psychiatric, and/or peripheral symptoms. Any symptom known to one of skill in the art to be associated with Huntington's disease can be ameliorated or otherwise modulated as set forth above in the methods described above. In certain embodiments, the symptom is a physical symptom selected from the group consisting of restlessness, lack of coordination, unintentionally initiated motions, unintentionally uncompleted motions, unsteady gait, chorea, rigidity, writhing motions, abnormal posturing, instability, abnormal facial expressions, difficulty chewing, difficulty swallowing, difficulty speaking, seizure, and sleep disturbances. In certain embodiments, the symptom is a cognitive symptom selected from the group consisting of impaired planning, impaired flexibility, impaired abstract thinking, impaired rule acquisition, impaired initiation of appropriate actions, impaired inhibition of inappropriate actions, impaired short-term memory, impaired long-term memory, paranoia, disorientation, confusion, hallucination and dementia. In certain embodiments, the symptom is a psychiatric symptom selected from the group consisting of anxiety, depression, blunted affect, egocentrisms, aggression, compulsive behavior, irritability and suicidal ideation. In certain embodiments, the symptom is a peripheral symptom selected from the group consisting of reduced brain mass, muscle atrophy, cardiac failure, impaired glucose tolerance, weight loss, osteoporosis, and testicular atrophy.

In certain embodiments, the symptom is restlessness. In certain embodiments, the symptom is lack of coordination. In certain embodiments, the symptom is unintentionally initiated motions. In certain embodiments, the symptom is unintentionally uncompleted motions. In certain embodiments, the symptom is unsteady gait. In certain embodiments, the symptom is chorea. In certain embodiments, the symptom is rigidity. In certain embodiments, the symptom is writhing motions. In certain embodiments, the symptom is abnormal posturing. In certain embodiments, the symptom is instability. In certain embodiments, the symptom is abnormal facial expressions. In certain embodiments, the symptom is difficulty chewing. In certain embodiments, the symptom is difficulty swallowing. In certain embodiments, the symptom is difficulty speaking. In certain embodiments, the symptom is seizures. In certain embodiments, the symptom is sleep disturbances.

In certain embodiments, the symptom is impaired planning. In certain embodiments, the symptom is impaired flexibility. In certain embodiments, the symptom is impaired abstract thinking. In certain embodiments, the symptom is impaired rule acquisition. In certain embodiments, the symptom is impaired initiation of appropriate actions. In certain embodiments, the symptom is impaired inhibition of inappropriate actions. In certain embodiments, the symptom is impaired short-term memory. In certain embodiments, the symptom is impaired long-term memory. In certain embodiments, the symptom is paranoia. In certain embodiments, the symptom is disorientation. In certain embodiments, the symptom is confusion. In certain embodiments, the symptom is hallucination. In certain embodiments, the symptom is dementia.

In certain embodiments, the symptom is anxiety. In certain embodiments, the symptom is depression. In certain embodiments, the symptom is blunted affect. In certain embodiments, the symptom is egocentrism. In certain embodiments, the symptom is aggression. In certain embodiments, the symptom is compulsive behavior. In certain embodiments, the symptom is irritability. In certain embodiments, the symptom is suicidal ideation.

In certain embodiments, the symptom is reduced brain mass. In certain embodiments, the symptom is muscle atrophy. In certain embodiments, the symptom is cardiac failure. In certain embodiments, the symptom is impaired glucose tolerance. In certain embodiments, the symptom is weight loss. In certain embodiments, the symptom is osteoporosis. In certain embodiments, the symptom is testicular atrophy.

In certain embodiments, symptoms of Huntington's disease may be quantifiable. For example, osteoporosis may be measured and quantified by, for example, bone density scans. For such symptoms, in certain embodiments, the symptom may be reduced by about 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 99%, or a range defined by any two of these values.

In certain embodiments, provided are methods of treating an individual comprising administering one or more pharmaceutical compositions as described herein. In certain embodiments, the individual has Huntington's disease.

In certain embodiments, administration of an antisense compound targeted to a huntingtin nucleic acid results in reduction of huntingtin expression by at least about 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 99%, or a range defined by any two of these values.

In certain embodiments, pharmaceutical compositions comprising an antisense compound targeted to huntingtin are used for the preparation of a medicament for treating a patient suffering or susceptible to Huntington's disease.

In certain embodiments, the methods described herein include administering a compound comprising a modified oligonucleotide having a contiguous nucleobases portion as described herein of a sequence recited in SEQ ID NO: 6, 9, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 35, 36, 10, 11, 12, 13, 18, 22 or 32. In certain embodiments, the methods described herein include administering a compound comprising a modified oligonucleotide having a contiguous nucleobases portion as described herein of a sequence recited in SEQ ID NOs: 12, 22, 28, 30, 32, and 33.

Administration

In certain embodiments, the compounds and compositions as described herein are administered parenterally.

In certain embodiments, parenteral administration is by infusion. Infusion can be chronic or continuous or short or intermittent. In certain embodiments, infused pharmaceutical agents are delivered with a pump. In certain embodiments, parenteral administration is by injection.

In certain embodiments, compounds and compositions are delivered to the CNS. In certain embodiments, compounds and compositions are delivered to the cerebrospinal fluid. In certain embodiments, compounds and compositions are administered to the brain parenchyma. In certain embodiments, compounds and compositions are delivered to an animal by intrathecal administration, or intracerebroventricular administration. Broad distribution of compounds and compositions, described herein, within the central nervous system may be achieved with intraparenchymal administration, intrathecal administration, or intracerebroventricular administration.

In certain embodiments, parenteral administration is by injection. The injection may be delivered with a syringe or a pump. In certain embodiments, the injection is a bolus injection. In certain embodiments, the injection is administered directly to a tissue, such as striatum, caudate, cortex, hippocampus and cerebellum.

The median effective concentration ($EC_{50}$) of an antisense compounds for inhibiting huntingtin mRNA expression was calculated after either ICV infusion or bolus injection (see Examples 9 and 10). The $EC_{50}$ for the compound after intrastriatal injection was determined to be 0.45 μg/g. The $EC_{50}$ after ICV administration was determined to be 26.4 μg/g.

Therefore, in certain embodiments, delivery of a compound or composition described herein can affect the pharmacokinetic profile of the compound or composition. In certain embodiments, injection of a compound or composition described herein, to a targeted tissue improves the pharmacokinetic profile of the compound or composition as compared to infusion of the compound or composition. In a certain embodiment, the injection of a compound or composition improves potency compared to broad diffusion, requiring less of the compound or composition to achieve similar pharmacology. In certain embodiments, similar pharmacology refers to the amount of time that a target mRNA and/or target protein is down-regulated (e.g. duration of action). In certain embodiments, methods of specifically localizing a pharmaceutical agent, such as by bolus injection, decreases median effective concentration (EC50) by a factor of about 50 (e.g. 50 fold less concentration in tissue is required to achieve the same or similar pharmacodynamic effect). In certain embodiments, methods of specifically localizing a pharmaceutical agent, such as by bolus injection, decreases median effective concentration (EC50) by a factor of 20, 25, 30, 35, 40, 45 or 50. In certain embodiments the pharmaceutical agent in an antisense compound as further described herein. In certain embodiments, the targeted tissue is brain tissue. In certain embodiments the targeted tissue is striatal tissue. In certain embodiments, decreasing EC50 is desirable because it reduces the dose required to achieve a pharmacological result in a patient in need thereof.

The half-life of MOE gapmer oligonucleotides in brain tissue is about 20 days (see Examples 9-11). The duration of action as measured by inhibition of huntingtin mRNA is prolonged in the brain (see Examples 9 and 10). Intracerebroventricular infusion of antisense oligonucleotides for 2 weeks results in inhibition of huntingtin mRNA by at least 50% in striatal tissue of BACHD mice for at least 91 days after termination of dosing. Administration by bolus injection resulted in a similar duration of action.

In certain embodiments, delivery of a compound or composition, as described herein, to the CNS results in 47% down-regulation of a target mRNA and/or target protein for at least 91 days. In certain embodiments, delivery of a compound or composition results in at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, or at least 75% down-regulation of a target mRNA and/or target protein for at least 20 days, at least 30 days, at least 40 days, at least 50 days, at least 60 days, at least 70 days, at least 80 days, at least 85 days, at least 90 days, at least 95 days, at least 100 days, at least 110 days, at least 120 days. In certain embodiments, delivery to the CNS is by intraparenchymal administration, intrathecal administration, or intracerebroventricular administration.

In certain embodiments, an antisense oligonucleotide is delivered by injection or infusion once every month, every two months, every 90 days, every 3 months, every 6 months, twice a year or once a year.

Certain Combination Therapies

In certain embodiments, one or more pharmaceutical compositions are co-administered with one or more other pharmaceutical agents. In certain embodiments, such one or more other pharmaceutical agents are designed to treat the same disease, disorder, or condition as the one or more pharmaceutical compositions described herein. In certain embodiments, such one or more other pharmaceutical agents are designed to treat a different disease, disorder, or condition as the one or more pharmaceutical compositions described herein. In certain embodiments, such one or more other pharmaceutical agents are designed to treat an undesired side effect of one or more pharmaceutical compositions as described herein. In certain embodiments, one or more pharmaceutical compositions are co-administered with another pharmaceutical agent to treat an undesired effect of that other pharmaceutical agent. In certain embodiments, one or more pharmaceutical compositions are co-administered with another pharmaceutical agent to produce a combinational effect. In certain embodiments, one or more pharmaceutical compositions are co-administered with another pharmaceutical agent to produce a synergistic effect.

In certain embodiments, one or more pharmaceutical compositions and one or more other pharmaceutical agents are administered at the same time. In certain embodiments, one or more pharmaceutical compositions and one or more other pharmaceutical agents are administered at different times. In certain embodiments, one or more pharmaceutical compositions and one or more other pharmaceutical agents are prepared together in a single formulation. In certain embodiments, one or more pharmaceutical compositions and one or more other pharmaceutical agents are prepared separately.

In certain embodiments, pharmaceutical agents that may be co-administered with a pharmaceutical composition of include antipsychotic agents, such as, e.g., haloperidol, chlorpromazine, clozapine, quetapine, and olanzapine; antidepressant agents, such as, e.g., fluoxetine, sertraline hydrochloride, venlafaxine and nortriptyline; tranquilizing agents such as, e.g., benzodiazepines, clonazepam, paroxetine, venlafaxin, and beta-blockers; mood-stabilizing agents such as, e.g., lithium, valproate, lamotrigine, and carbamazepine; paralytic agents such as, e.g., Botulinum toxin; and/or other experimental agents including, but not limited to, tetrabenazine (Xenazine), creatine, conezyme Q10, trehalose, docosahexanoic acids, ACR16, ethyl-EPA, atomoxetine, citalopram, dimebon, memantine, sodium phenylbutyrate, ramelteon, ursodiol, zyprexa, xenasine, tiapride, riluzole, amantadine, [123I]MNI-420, atomoxetine, tetrabenazine, digoxin, detromethorphan, warfarin, alprozam, ketoconazole, omeprazole, and minocycline.

## EXAMPLES

### Non-Limiting Disclosure and Incorporation by Reference

While certain compounds, compositions and methods described herein have been described with specificity in accordance with certain embodiments, the following examples serve only to illustrate the compounds described herein and are not intended to limit the same. Each of the references recited in the present application is incorporated herein by reference in its entirety.

### Example 1

### Antisense oligonucleotides targeted to human huntingtin gene sequences

About seventeen hundred newly designed antisense compounds of various lengths, motifs and backbone composition targeting the human huntingtin gene sequence were tested for their effect on human huntingtin mRNA in vitro in several cell types. These gapmers were further designed with internucleoside linkages that are either only phosphorothioate linkages (described in Table 1) or that are phosphorothioate and phosphodiester linkages (described in Table 5). A number of the newly designed oligos and two benchmark oligonucleotides (previously designed and disclosed) are provided in Tables 1 and 5.

Gapmers with Fully Phosphorothioate Internucleoside Linkages

Certain of the compounds presented in Table 1 have a motif of 5-10-5 MOE, 6-8-6 MOE, or 5-8-5 MOE. The 5-10-5 gapmers have twenty linked nucleosides, wherein the central gap segment has ten 2'-deoxynucleosides and is flanked on both sides (in the 5' and 3' directions) by wings having five nucleosides each. The 6-8-6 gapmer has twenty linked nucleosides, wherein the central gap segment has eight 2'-deoxynucleosides and is flanked on both sides (in the 5' and 3' directions) by wings having six nucleosides each. The 5-8-5 gapmers have eighteen linked nucleosides, wherein the central gap segment has eight 2'-deoxynucleosides and is flanked on both sides (in the 5' and 3' directions) by wings having five nucleosides each. For all gapmers listed in Table 1, each nucleoside in the 5' wing segment and each nucleoside in the 3' wing segment has a 2'-MOE modification. The internucleoside linkages throughout each gapmer are phosphorothioate (P═S) internucleoside linkages. All cytosines throughout each gapmer are 5-methylcytosines. Each gapmer in Table 1 is targeted to SEQ ID NO: 1 (GENBANK Accession No. NM_002111.6) or SEQ ID NO: 2 (GENBANK Accession No. NT_006081.17 truncated from nucleotides 462000 to 634000). 'Start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human gene sequence.

TABLE 1

Chimeric antisense oligonucleotides with phosphorothioate internucleoside linkages targeting human huntingtin gene sequences (SEQ ID NOs: 1 and 2)

| Start Site | Stop Site | Target SEQ ID NO. | ISIS No. | Sequence (5' to 3') | Motif | SEQ ID NO. |
|---|---|---|---|---|---|---|
| 4384 | 4403 | 1 | 436665 | TAGCATTCTTATCTGCACGG | 5-10-5 | 6 |
| 4511 | 4530 | 1 | 436668 | ACCCGTAACTGAACCAGCTG | 5-10-5 | 7 |
| 4599 | 4618 | 1 | 419627 | TTCCCTGAACTGGCCCACTT | 5-10-5 | 8 |
| 4605 | 4624 | 1 | 419628 | CTCTGATTCCCTGAACTGGC | 5-10-5 | 9 |
| 4607 | 4626 | 1 | 444607 | GCCTCTGATTCCCTGAACTG | 5-10-5 | 10 |
| 4608 | 4627 | 1 | 419629 | TGCCTCTGATTCCCTGAACT | 5-10-5 | 11 |
| 4608 | 4627 | 1 | 444578 | TGCCTCTGATTCCCTGAACT | 6-8-6 | 11 |
| 4609 | 4628 | 1 | 436671 | TTGCCTCTGATTCCCTGAAC | 5-10-5 | 12 |
| 4610 | 4629 | 1 | 444608 | ATTGCCTCTGATTCCCTGAA | 5-10-5 | 13 |
| 4617 | 4636 | 1 | 444615 | TGGAATGATTGCCTCTGATT | 5-10-5 | 14 |
| 4622 | 4639 | 1 | 437168 | GTTTGGAATGATTGCCTC | 5-8-5 | 15 |
| 4679 | 4698 | 1 | 419630 | CCAATGATCTGTTTTGAATG | 5-10-5 | 16 |
| 4733 | 4752 | 1 | 419636 | GCCTTCCTTCCACTGGCCAT | 5-10-5 | 17 |
| 4813 | 4832 | 1 | 444618 | CTGCATCAGCTTTATTTGTT | 5-10-5 | 18 |
| 4814 | 4833 | 1 | 419637 | CCTGCATCAGCTTTATTTGT | 5-10-5 | 19 |
| 4823 | 4842 | 1 | 444627 | AGCTCTTTTCCTGCATCAGC | 5-10-5 | 20 |
| 4860 | 4877 | 1 | 437507 | GTAACATTGACACCACCA | 5-8-5 | 21 |
| 4862 | 4881 | 1 | 388241 | CTCAGTAACATTGACACCAC | 5-10-5 | 22 |
| 4868 | 4887 | 1 | 436684 | ATGAGTCTCAGTAACATTGA | 5-10-5 | 23 |

TABLE 1-continued

Chimeric antisense oligonucleotides with phosphorothioate internucleoside linkages targeting human huntingtin gene sequences (SEQ ID NOs: 1 and 2)

| Start Site | Stop Site | Target SEQ ID NO. | ISIS No. | Sequence (5' to 3') | Motif | SEQ ID NO. |
|---|---|---|---|---|---|---|
| 4925 | 4944 | 1 | 419640 | TCCTTGTGGCACTGCTGCAG | 5-10-5 | 24 |
| 4928 | 4947 | 1 | 419641 | TTCTCCTTGTGGCACTGCTG | 5-10-5 | 25 |
| 4931 | 4950 | 1 | 419642 | TCATTCTCCTTGTGGCACTG | 5-10-5 | 26 |
| 4931 | 4948 | 1 | 437442 | ATTCTCCTTGTGGCACTG | 5-8-5 | 27 |
| 4955 | 4974 | 1 | 436689 | CGAGACAGTCGCTTCCACTT | 5-8-5 | 28 |
| 4960 | 4977 | 1 | 437175 | TGTCGAGACAGTCGCTTC | 5-8-5 | 29 |
| 5801 | 5820 | 1 | 444584 | TTGCACATTCCAAGTTTGGC | 5-10-5 | 30 |
| 5807 | 5826 | 1 | 387916 | TCTCTATTGCACATTCCAAG | 5-10-5 | 31 |
| 5809 | 5828 | 1 | 444591 | TTTCTCTATTGCACATTCCA | 5-10-5 | 32 |
| 5809 | 5826 | 1 | 437527 | TCTCTATTGCACATTCCA | 5-8-5 | 33 |
| 1446 | 1465 | 2 | 388817 | GCAGGGTTACCGCCATCCCC | 5-10-5 | 34 |
| 101088 | 101105 | 2 | 437441 | ACCTTATCTGCACGGTTC | 5-8-5 | 35 |
| 115066 | 115085 | 2 | 436754 | CTCTCTGTGTATCACCTTCC | 5-10-5 | 36 |

The complementarity of the gapmers in Table 1 with mouse, rhesus monkey and rat huntingtin gene sequences is further described in Tables 2, 3, and 4.

The gapmers of Table 2 are complementary with mouse huntingtin mRNA (GENBANK Accession No. NM_010414.1, designated herein as SEQ ID NO: 3). 'Mouse target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the mouse mRNA. 'Mouse target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the mouse mRNA. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the mouse mRNA sequence.

TABLE 2

Complementarity of antisense oligonucleotides having phosphorothioate linkages with murine mRNA (SEQ ID NO: 3)

| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Mouse Start Site | Mouse Stop Site | No. of mismatches | SEQ ID NO. |
|---|---|---|---|---|---|---|---|
| 4384 | 4403 | 1 | 436665 | 4343 | 4362 | 0 | 6 |
| 4511 | 4530 | 1 | 436668 | 4470 | 4489 | 1 | 7 |
| 4599 | 4618 | 1 | 419627 | 4558 | 4577 | 0 | 8 |
| 4605 | 4624 | 1 | 419628 | 4564 | 4583 | 0 | 9 |
| 4607 | 4626 | 1 | 444607 | 4566 | 4585 | 0 | 10 |
| 4608 | 4627 | 1 | 419629 | 4567 | 4586 | 0 | 11 |
| 4608 | 4627 | 1 | 444578 | 4567 | 4586 | 0 | 11 |
| 4609 | 4628 | 1 | 436671 | 4568 | 4587 | 0 | 12 |
| 4610 | 4629 | 1 | 444608 | 4569 | 4588 | 0 | 13 |
| 4617 | 4636 | 1 | 444615 | 4576 | 4595 | 1 | 14 |
| 4622 | 4639 | 1 | 437168 | 4581 | 4598 | 2 | 15 |
| 4679 | 4698 | 1 | 419630 | 4638 | 4657 | 0 | 16 |
| 4733 | 4752 | 1 | 419636 | 4692 | 4711 | 0 | 17 |
| 4813 | 4832 | 1 | 444618 | 4772 | 4791 | 0 | 18 |
| 4814 | 4833 | 1 | 419637 | 4773 | 4792 | 0 | 19 |
| 4823 | 4842 | 1 | 444627 | 4782 | 4801 | 1 | 20 |
| 4925 | 4944 | 1 | 419640 | 4884 | 4903 | 0 | 24 |
| 4928 | 4947 | 1 | 419641 | 4887 | 4906 | 0 | 25 |
| 4931 | 4950 | 1 | 419642 | 4890 | 4909 | 0 | 26 |
| 4931 | 4948 | 1 | 437442 | 4890 | 4907 | 0 | 27 |
| 4955 | 4974 | 1 | 436689 | 4914 | 4933 | 3 | 28 |
| 5807 | 5826 | 1 | 387916 | 5763 | 5782 | 1 | 31 |
| 5809 | 5826 | 1 | 437527 | 5765 | 5782 | 1 | 33 |

TABLE 2-continued

| Complementarity of antisense oligonucleotides having phosphorothioate linkages with murine mRNA (SEQ ID NO: 3) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Mouse Start Site | Mouse Stop Site | No. of mismatches | SEQ ID NO. |
| 5809 | 5828 | 1 | 444591 | 5765 | 5784 | 1 | 32 |
| 101088 | 101105 | 2 | 437441 | 4340 | 4357 | 2 | 35 |

The gapmers of Table 3 are complementary with the rhesus monkey huntingtin genomic sequence (the complement of GENBANK Accession No. NW_001109716.1 truncated at nucleotides 698000 to 866000, designated herein as SEQ ID NO: 4). 'Rhesus monkey target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the rhesus monkey gene sequence. 'Rhesus monkey target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the rhesus monkey gene sequence. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the rhesus monkey gene sequence.

The gapmers of Table 4 are complementary with rat huntingtin mRNA (GENBANK Accession No. NM_024357.2, designated herein as SEQ ID NO: 5). 'Rat target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the rat mRNA. 'Rat target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the rat mRNA. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human gene sequence. 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the rat mRNA sequence.

TABLE 3

| Complementarity of antisense oligonucleotides having phosphorothioate linkages with rhesus monkey gene sequence (SEQ ID NO: 4) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Rhesus monkey Start Site | Rhesus monkey Stop Site | No. of mismatches | SEQ ID NO. |
| 4511 | 4530 | 1 | 436665 | 98182 | 98201 | 0 | 6 |
| 4599 | 4618 | 1 | 419627 | 101353 | 101372 | 1 | 8 |
| 4609 | 4628 | 1 | 436671 | 102256 | 102275 | 3 | 12 |
| 4610 | 4629 | 1 | 444608 | 102257 | 102276 | 2 | 13 |
| 4617 | 4636 | 1 | 444615 | 102264 | 102283 | 0 | 14 |
| 4622 | 4639 | 1 | 437168 | 102269 | 102286 | 0 | 15 |
| 4679 | 4698 | 1 | 419630 | 102326 | 102345 | 0 | 16 |
| 4733 | 4752 | 1 | 419636 | 102380 | 102399 | 0 | 17 |
| 4813 | 4832 | 1 | 444618 | 105030 | 105049 | 0 | 18 |
| 4814 | 4833 | 1 | 419637 | 105031 | 105050 | 0 | 19 |
| 4823 | 4842 | 1 | 444627 | 105040 | 105059 | 0 | 20 |
| 4860 | 4877 | 1 | 437507 | 105077 | 105094 | 1 | 21 |
| 4862 | 4881 | 1 | 388241 | 105079 | 105098 | 1 | 22 |
| 4868 | 4887 | 1 | 436684 | 105085 | 105104 | 0 | 23 |
| 4925 | 4944 | 1 | 419640 | 106844 | 106863 | 0 | 24 |
| 4928 | 4947 | 1 | 419641 | 106847 | 106866 | 0 | 25 |
| 4931 | 4950 | 1 | 419642 | 106850 | 106869 | 0 | 26 |
| 4931 | 4948 | 1 | 437442 | 106850 | 106867 | 0 | 27 |
| 4955 | 4974 | 1 | 436689 | 106874 | 106893 | 0 | 28 |
| 4960 | 4977 | 1 | 437175 | 106879 | 106896 | 0 | 29 |
| 5801 | 5820 | 1 | 444584 | 125331 | 125350 | 0 | 30 |
| 5807 | 5826 | 1 | 387916 | 125337 | 125356 | 0 | 31 |
| 5809 | 5826 | 1 | 437527 | 125339 | 125356 | 0 | 33 |
| 5809 | 5828 | 1 | 444591 | 125339 | 125358 | 0 | 32 |
| 101088 | 101105 | 2 | 437441 | 97904 | 97921 | 0 | 35 |
| 115066 | 115085 | 2 | 436754 | 110518 | 110537 | 0 | 36 |

TABLE 4

| Complementarity of antisense oligonucleotides having phosphorothioate linkages with rat mRNA (SEQ ID NO: 5) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Rat Start Site | Rat Stop Site | No. of mismatches | SEQ ID NO. |
| 4384 | 4403 | 1 | 436665 | 4343 | 4362 | 1 | 6 |
| 4511 | 4530 | 1 | 436668 | 4470 | 4489 | 1 | 7 |
| 4599 | 4618 | 1 | 419627 | 4558 | 4577 | 0 | 8 |
| 4605 | 4624 | 1 | 419628 | 4564 | 4583 | 0 | 9 |
| 4607 | 4626 | 1 | 444607 | 4566 | 4585 | 0 | 10 |
| 4608 | 4627 | 1 | 419629 | 4567 | 4586 | 0 | 11 |
| 4608 | 4627 | 1 | 444578 | 4567 | 4586 | 0 | 11 |
| 4609 | 4628 | 1 | 436671 | 4568 | 4587 | 0 | 12 |
| 4610 | 4629 | 1 | 444608 | 4569 | 4588 | 0 | 13 |
| 4617 | 4636 | 1 | 444615 | 4576 | 4595 | 1 | 14 |
| 4622 | 4639 | 1 | 437168 | 4581 | 4598 | 2 | 15 |
| 4679 | 4698 | 1 | 419630 | 4638 | 4657 | 0 | 16 |
| 4733 | 4752 | 1 | 419636 | 4692 | 4711 | 0 | 17 |
| 4813 | 4832 | 1 | 444618 | 4772 | 4791 | 0 | 18 |
| 4814 | 4833 | 1 | 419637 | 4773 | 4792 | 0 | 19 |
| 4823 | 4842 | 1 | 444627 | 4782 | 4801 | 1 | 20 |
| 4925 | 4944 | 1 | 419640 | 4884 | 4903 | 1 | 24 |
| 4928 | 4947 | 1 | 419641 | 4887 | 4906 | 1 | 25 |
| 4931 | 4950 | 1 | 419642 | 4890 | 4909 | 1 | 26 |
| 4931 | 4948 | 1 | 437442 | 4890 | 4907 | 1 | 27 |
| 4955 | 4974 | 1 | 436689 | 4914 | 4933 | 3 | 28 |
| 5801 | 5820 | 1 | 444584 | 5757 | 5776 | 3 | 30 |
| 5807 | 5826 | 1 | 387916 | 5763 | 5782 | 0 | 31 |
| 5809 | 5826 | 1 | 437527 | 5765 | 5782 | 0 | 33 |
| 5809 | 5828 | 1 | 444591 | 5765 | 5784 | 0 | 32 |
| 101088 | 101105 | 2 | 437441 | 4340 | 4357 | 2 | 35 |

Gapmers with Mixed Phosphorothioate and Phosphodiester Internucleoside Linkages

The chimeric antisense oligonucleotides in Table 5 were designed as 5-10-5 MOE gapmers. The 5-10-5 gapmers have twenty linked nucleosides, wherein the central gap segment has ten 2'-deoxynucleotides and is flanked on both sides (in the 5' and 3' directions) by wings having five nucleosides each. Each nucleoside in the 5' wing segment and each nucleoside in the 3' wing segment has a 2'-MOE modification. The internucleoside linkages within the central gap segment, the linkages connecting the gap segment to the 5' or 3' wing segment, and the linkages for the 5'-most and 3'-most nucleosides of each wing segments are all phosphorothioate (P═S) linkages; the internucleoside linkages connecting the rest of the nucleosides of both the 5' and 3' wing segments are phosphodiester linkages; i.e. the gapmer has a mixed backbone. All cytosines throughout each gapmer are 5-methylcytosines. Each gapmer in Table 5 is targeted to the human mRNA sequence (GENBANK Accession No. NM_002111.6, designated herein as SEQ ID NO: 1). 'Start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human mRNA. 'Stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human mRNA.

TABLE 5

| Chimeric antisense oligonucleotides with phosphorothioate and phosphate internucleoside linkages targeting human huntingtin mRNA (SEQ ID NO: 1) | | | | | | |
|---|---|---|---|---|---|---|
| Start Site | Stop Site | Target SEQ ID NO. | ISIS No. | Sequence (5' to 3') | Motif | SEQ ID NO. |
| 4607 | 4626 | 1 | 444658 | GCCTCTGATTCCCTGAACTG | 5-10-5 | 10 |
| 4608 | 4627 | 1 | 444659 | TGCCTCTGATTCCCTGAACT | 5-10-5 | 11 |
| 4609 | 4628 | 1 | 444660 | TTGCCTCTGATTCCCTGAAC | 5-10-5 | 12 |
| 4610 | 4629 | 1 | 444661 | ATTGCCTCTGATTCCCTGAA | 5-10-5 | 13 |
| 4813 | 4832 | 1 | 444663 | CTGCATCAGCTTTATTTGTT | 5-10-5 | 18 |
| 4862 | 4881 | 1 | 443139 | CTCAGTAACATTGACACCAC | 5-10-5 | 22 |

TABLE 5-continued

| Chimeric antisense oligonucleotides with phosphorothioate and phosphate internucleoside linkages targeting human huntingtin mRNA (SEQ ID NO: 1) | | | | | | |
|---|---|---|---|---|---|---|
| Start Site | Stop Site | Target SEQ ID NO. | ISIS No. | Sequence (5' to 3') | Motif | SEQ ID NO. |
| 5809 | 5828 | 1 | 444652 | TTTCTCTATTGCACATTCCA | 5-10-5 | 32 |
| 4928 | 4947 | 1 | 451541 | TTCTCCTTGTGGCACTGCTG | 5-10-5 | 25 |

The complementarity of the gapmers in Table 5 with mouse, rhesus monkey and rat huntingtin gene sequences are further described in Tables 6, 7, and 8.

The gapmers of Table 6 are complementary with mouse huntingtin mRNA (GENBANK Accession No. NM_010414.1; SEQ ID NO: 3). 'Mouse target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the mouse mRNA. 'Mouse target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the mouse mRNA. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the mouse mRNA sequence.

TABLE 6

| Complementarity of antisense oligonucleotides having mixed phosphorothioate and phosphate linkages with murine mRNA (SEQ ID NO: 3) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Mouse Start Site | Mouse Stop Site | No. of mismatches | SEQ ID NO. |
| 4607 | 4626 | 1 | 444658 | 4566 | 4585 | 0 | 10 |
| 4608 | 4627 | 1 | 444659 | 4567 | 4586 | 0 | 11 |
| 4609 | 4628 | 1 | 444660 | 4568 | 4587 | 0 | 12 |
| 4610 | 4629 | 1 | 444661 | 4569 | 4588 | 0 | 13 |
| 4813 | 4832 | 1 | 444663 | 4772 | 4791 | 0 | 18 |
| 5809 | 5828 | 1 | 444652 | 5765 | 5784 | 1 | 32 |

The gapmers of Table 7 are complementary with the rhesus monkey huntingtin genomic sequence (the complement of GENBANK Accession No. NW_001109716.1 truncated at nucleotides 698000 to 866000; SEQ ID NO: 4). 'Rhesus monkey target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the rhesus monkey gene sequence. 'Rhesus monkey target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the rhesus monkey gene sequence. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the rhesus monkey gene sequence.

TABLE 7

| Complementarity of antisense oligonucleotides having mixed phosphorothioate and phosphate linkages with rhesus monkey gene sequence (SEQ ID NO: 4) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Rhesus monkey Start Site | Rhesus monkey Stop Site | No. of mismatches | SEQ ID NO. |
| 4609 | 4628 | 1 | 444660 | 102256 | 102275 | 3 | 12 |
| 4610 | 4629 | 1 | 444661 | 102257 | 102276 | 2 | 13 |
| 4813 | 4832 | 1 | 444663 | 105030 | 105049 | 0 | 18 |
| 4862 | 4881 | 1 | 443139 | 105079 | 105098 | 1 | 22 |
| 5809 | 5828 | 1 | 444652 | 125339 | 125358 | 0 | 32 |

The gapmers of Table 8 are complementary with rat huntingtin mRNA (GENBANK Accession No. NM_024357.2; SEQ ID NO: 5). 'Rat target start site' indicates the 5'-most nucleotide to which the gapmer is targeted in the rat mRNA. 'Rat target stop site' indicates the 3'-most nucleotide to which the gapmer is targeted in the rat mRNA. 'Human Target Start Site' indicates the 5'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Human Target Stop Site' indicates the 3'-most nucleotide to which the gapmer is targeted in the human mRNA (GENBANK Accession No. NM_002111.6). 'Number of mismatches' indicates the number of mismatches between the human oligonucleotide and the rat mRNA sequence.

TABLE 8

Complementarity of antisense oligonucleotides having mixed phosphorothioate and phosphate linkages with rat mRNA (SEQ ID NO: 5)

| Human Start Site | Human Stop Site | Human Target SEQ ID NO. | ISIS No. | Rat Start Site | Rat Stop Site | No. of mismatches | SEQ ID NO. |
|---|---|---|---|---|---|---|---|
| 4607 | 4626 | 1 | 444658 | 4566 | 4585 | 0 | 10 |
| 4608 | 4627 | 1 | 444659 | 4567 | 4586 | 0 | 11 |
| 4609 | 4628 | 1 | 444660 | 4568 | 4587 | 0 | 12 |
| 4610 | 4629 | 1 | 444661 | 4569 | 4588 | 0 | 13 |
| 4813 | 4832 | 1 | 444663 | 4772 | 4791 | 0 | 18 |
| 5809 | 5828 | 1 | 444652 | 5765 | 5784 | 0 | 32 |

## Example 2

### Dose-Dependent Antisense Inhibition of Human Huntingtin mRNA In Vitro

About seventeen hundred newly designed antisense compounds of various lengths, motifs and backbone composition were tested for their effect on human huntingtin mRNA in vitro in several cell types. These compounds were compared to about two hundred and fifty previously designed compounds including the compound ISIS 387916 which was previously determined to be a compound of considerable potency in vivo. As shown in this example, ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436671, ISIS 436689, ISIS 437507, ISIS 443139, ISIS 444591, ISIS 444661, ISIS 437527, ISIS 444584, and ISIS 444652 and previously designed ISIS 388241 were found to have similar or better potency than the benchmark compound ISIS 387916 in vitro.

A. GM04281 Fibroblasts

Cultured GM04281 fibroblasts at a density of 25,000 cells per well were transfected using electroporation with 500 nM, 1000 nM, 2000 nM, 4000 nM, or 8000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 (forward sequence CTCCGTCCGGTAGACATGCT, designated herein as SEQ ID NO: 37; reverse sequence GGAAATCAGAACCCTCAAAATGG, designated herein as SEQ ID NO: 38; probe sequence TGAGCACTGTTCAACTGTGGATATCGGGAX, designated herein as SEQ ID NO: 39) was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 9 as percent inhibition of huntingtin mRNA, relative to untreated control cells and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels.

The half maximal inhibitory concentration ($IC_{50}$) of each oligonucleotide is also presented in Table 9 and was calculated by plotting the concentrations of oligonucleotides used versus the percent inhibition of huntingtin mRNA expression achieved at each concentration, and noting the concentration of oligonucleotide at which 50% inhibition of huntingtin mRNA expression was achieved compared to the control. The $IC_{50}$ is expressed in μM.

TABLE 9

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No. | 500 nM | 1000 nM | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (μM) |
|---|---|---|---|---|---|---|
| 387916 | 33 | 73 | 90 | 96 | 97 | 1.00 |
| 388241 | 44 | 70 | 82 | 95 | 97 | 0.61 |
| 419641 | 26 | 32 | 71 | 90 | 93 | 1.06 |
| 436665 | 56 | 67 | 87 | 95 | 96 | 0.32 |
| 436671 | 12 | 35 | 68 | 82 | 91 | 1.55 |
| 436689 | 10 | 34 | 61 | 80 | 91 | 1.89 |

ISIS 387916, ISIS 388241, and ISIS 437507 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts were tested in a similar procedure, as described above. The results are presented in Table 10 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 10 expressed in μM.

TABLE 10

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No. | 500 nM | 1000 nM | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (μM) |
|---|---|---|---|---|---|---|
| 387916 | 56 | 84 | 94 | 98 | 99 | 0.34 |
| 388241 | 58 | 75 | 94 | 98 | 99 | 0.23 |
| 437507 | 61 | 74 | 85 | 93 | 93 | 0.22 |

ISIS 387916, ISIS 388241, and ISIS 437507 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts were tested in a similar procedure as described above. The results are presented in Table 11 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 11 expressed in µM.

TABLE 11

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No. | 500 nM | 1000 nM | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (µM) |
|---|---|---|---|---|---|---|
| 387916 | 40 | 61 | 85 | 94 | 97 | 0.70 |
| 388241 | 51 | 72 | 86 | 94 | 98 | 0.41 |
| 437507 | 30 | 55 | 71 | 79 | 82 | 1.07 |

ISIS 387916, ISIS 388241, ISIS 419641, and ISIS 436754 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts were tested in a similar procedure as described above. The results are presented in Table 12 as percent inhibition of huntingtin mRNA, relative to untreated control cells and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 12 expressed in µM.

TABLE 12

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No. | 500 nM | 1000 nM | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (µM) |
|---|---|---|---|---|---|---|
| 387916 | 58 | 75 | 93 | 98 | 98 | 0.22 |
| 388241 | 40 | 68 | 85 | 95 | 98 | 0.73 |
| 419641 | 37 | 58 | 86 | 92 | 95 | 0.80 |
| 436754 | 44 | 62 | 63 | 84 | 93 | 0.59 |

ISIS 387916, ISIS 388241, and ISIS 437507 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts at a density of 25,000 cells per well were transfected using electroporation with 250 nM, 500 nM, 1000 nM, 2000 nM, 4000 nM or 8000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. The results are presented in Table 13 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 13 expressed in µM.

TABLE 13

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No. | 250 nM | 500 nM | 1000 Nm | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (µM) |
|---|---|---|---|---|---|---|---|
| 387916 | 10 | 9 | 61 | 85 | 97 | 99 | 0.79 |
| 388241 | 0 | 18 | 42 | 90 | 98 | 99 | 1.08 |
| 437507 | 1 | 0 | 32 | 71 | 92 | 98 | 1.30 |

ISIS 387916, ISIS 388241, ISIS 419628, ISIS 419629, ISIS 419637, ISIS 436684, ISIS 443139, ISIS 444584, ISIS 444615, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, and ISIS 444661 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts at a density of 25,000 cells per well were transfected using electroporation with 156.25 nM, 312.5 nM, 625 nM, 1250 nM, or 2500 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. The results are presented in Table 14 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The data presented is the average of two experiments. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 14 expressed in µM.

TABLE 14

Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts

| ISIS No | 156.25 nM | 312.5 Nm | 625 nM | 1250 nM | 2500 nM | $IC_{50}$ (µM) |
|---|---|---|---|---|---|---|
| 387916 | 19 | 22 | 44 | 62 | 85 | 0.73 |
| 388241 | 3 | 13 | 24 | 42 | 71 | 1.42 |
| 419628 | 56 | 45 | 59 | 71 | 83 | 0.20 |
| 419629 | 42 | 38 | 67 | 70 | 89 | 0.33 |
| 419637 | 24 | 17 | 32 | 61 | 77 | 0.91 |
| 436684 | 15 | 28 | 55 | 73 | 85 | 0.59 |
| 443139 | 13 | 45 | 50 | 64 | 81 | 0.61 |
| 444584 | 0 | 0 | 25 | 50 | 74 | 1.28 |
| 444615 | 36 | 35 | 37 | 38 | 70 | 0.12 |
| 444627 | 40 | 38 | 48 | 73 | 87 | 0.43 |
| 444652 | 15 | 28 | 55 | 73 | 85 | 0.59 |
| 444658 | 50 | 54 | 75 | 84 | 96 | 0.18 |
| 444659 | 47 | 61 | 69 | 79 | 93 | 0.18 |
| 444660 | 41 | 61 | 65 | 84 | 95 | 0.22 |
| 444661 | 47 | 59 | 72 | 84 | 96 | 0.19 |

ISIS 387916, ISIS 436671, ISIS 444661, ISIS 419641, and ISIS 436665 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts at a density of 25,000 cells per well were transfected using electroporation with 13.6719 nM, 27.3438 nM, 54.6875 nM, 109.375 nM, 218.75 nM, 437.5 nM, 875 nM, 1750 nM, 3500 nM, or 7000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. The results are presented in Table 15 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 15 expressed in µM.

TABLE 15

| Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ISIS No. | 13.6719 nM | 27.3438 nM | 54.6875 nM | 109.375 nM | 218.75 nM | 437.5 nM | 875 nM | 1750 nM | 3500 nM | 7000 nM | $IC_{50}$ (μM) |
| 387916 | 0 | 31 | 14 | 43 | 44 | 68 | 86 | 89 | 97 | 97 | 0.31 |
| 436671 | 0 | 0 | 21 | 31 | 54 | 73 | 77 | 83 | 88 | 97 | 0.31 |
| 444661 | 0 | 10 | 25 | 53 | 66 | 73 | 87 | 96 | 99 | 99 | 0.16 |
| 419641 | 5 | 23 | 33 | 48 | 44 | 75 | 79 | 90 | 94 | 98 | 0.17 |
| 436665 | 26 | 37 | 47 | 44 | 65 | 83 | 89 | 94 | 98 | 98 | 0.07 |

ISIS 387916, ISIS 388241, ISIS 437168, and ISIS 437175 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts at a density of 25,000 cells per well were transfected using electroporation with 250 nM, 500 nM, 1000 nM, 2000 nM, 4000 nM, and 8000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. The results are presented in Table 15.1 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 15.1 expressed in μM.

TABLE 15.1

| Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts | | | | | | | |
|---|---|---|---|---|---|---|---|
| ISIS No. | 250.0 nM | 500.0 nM | 1000.0 nM | 2000.0 nM | 4000.0 nM | 8000.0 nM | $IC_{50}$ |
| 387916 | 22 | 63 | 70 | 83 | 95 | 96 | 0.62 |
| 388241 | 17 | 45 | 65 | 87 | 96 | 97 | 0.56 |
| 437175 | 47 | 31 | 56 | 60 | 79 | 91 | 1.19 |
| 437168 | 32 | 46 | 64 | 81 | 89 | 95 | 0.59 |

ISIS 387916, ISIS 388241, ISIS 437441, and ISIS 437442 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts were tested in a similar procedure as described above. The results are presented in Table 15.2 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 15.2 expressed in μM.

TABLE 15.2

| Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts | | | | | | | |
|---|---|---|---|---|---|---|---|
| ISIS No. | 250.0 nM | 500.0 nM | 1000.0 nM | 2000.0 nM | 4000.0 nM | 8000.0 nM | $IC_{50}$ |
| 387916 | 26 | 47 | 58 | 79 | 91 | 95 | 0.65 |
| 388241 | 30 | 52 | 60 | 81 | 94 | 97 | 0.55 |
| 437441 | 25 | 37 | 56 | 69 | 86 | 47 | 0.81 |
| 437442 | 39 | 43 | 47 | 70 | 85 | 50 | 0.59 |

ISIS 387916, ISIS 388241, ISIS 437175, and ISIS 437527 were further tested for their effect on human huntingtin mRNA in vitro. Cultured GM04281 fibroblasts were tested in a similar procedure as described above. The results are presented in Table 15.3 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 15.3 expressed in μM.

TABLE 15.3

| Dose dependent reduction of huntingtin mRNA in GM04281 fibroblasts | | | | | | | |
|---|---|---|---|---|---|---|---|
| ISIS No. | 250.0 nM | 500.0 nM | 1000.0 nM | 2000.0 nM | 4000.0 nM | 8000.0 nM | $IC_{50}$ |
| 387916 | 40 | 45 | 47 | 76 | 92 | 96 | 0.50 |
| 388241 | 40 | 37 | 50 | 90 | 96 | 97 | 0.80 |
| 437175 | 48 | 55 | 55 | 63 | 80 | 93 | 0.37 |
| 437527 | 33 | 52 | 61 | 80 | 86 | 95 | 0.52 |

B. A549 Cells

Some of the antisense oligonucleotides described in Example 1 were tested for their effect on human huntingtin mRNA in vitro. Cultured A549 cells at a density of 4,000 cells per well were transfected using lipofectin transfection reagent with 7.4074 nM, 22.222 nM, 66.667 nM, or 200 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 16 as percent inhibition of huntingtin mRNA, relative to untreated control cells and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 16 expressed in nM.

TABLE 16

| Dose dependent reduction of huntingtin mRNA in A549 cells | | | | | |
|---|---|---|---|---|---|
| ISIS No. | 7.4074 nM | 22.222 nM | 66.667 nM | 200.00 nM | $IC_{50}$ (nM) |
| 387916 | 12 | 37 | 76 | 92 | 33 |
| 419640 | 21 | 45 | 73 | 93 | 27 |
| 419641 | 34 | 60 | 83 | 96 | 15 |
| 419642 | 30 | 58 | 85 | 95 | 16 |

ISIS 387916, ISIS 388241, and ISIS 437507 were further tested for their effect on human huntingtin mRNA in vitro. Cultured A549 cells at a density of 20,000 cells per well were transfected using electroporation with 250 nM, 500 nM, 1000 nM, 2000 nM, 4000 nM or 8000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. The results are presented in Table 17 expressed as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 17 expressed in μM.

TABLE 17

Dose dependent reduction of huntingtin mRNA in A549 cells

| ISIS No. | 250 nM | 500 nM | 1000 nM | 2000 nM | 4000 nM | 8000 nM | $IC_{50}$ (μM) |
|---|---|---|---|---|---|---|---|
| 387916 | 15 | 17 | 25 | 36 | 52 | 75 | 3.09 |
| 388241 | 12 | 22 | 38 | 58 | 77 | 91 | 1.43 |
| 437507 | 25 | 28 | 38 | 57 | 58 | 76 | 1.84 |

C. LLC-MK2 Cells

Some of the antisense oligonucleotides described in Example 1 and targeted to a human huntingtin nucleic acid were tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells at a density of 25,000 cells per well were transfected using electroporation with 625 nM, 1250 nM, 2500 nM, 5000 nM, 10,000 nM, or 20,000 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2686 (forward sequence GTCTGAGCCTCTCTCGGTCAA, designated herein as SEQ ID NO: 40; reverse sequence AAGGGATGCTGGGCTCTGT, designated herein as SEQ ID NO: 41; probe sequence AGCAAAGCTTGGTGTCTTGGCACTGTTAGTX, designated herein as SEQ ID NO: 42) was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 18 as percent inhibition of huntingtin mRNA, relative to untreated control cells and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 18 expressed in μM.

TABLE 18

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No. | 625 nM | 1250 nM | 2500 nM | 5000 nM | 10000 nM | 20000 nM | $IC_{50}$ (μM) |
|---|---|---|---|---|---|---|---|
| 388241 | 21 | 12 | 35 | 46 | 46 | 94 | 4.1 |
| 444591 | 37 | 46 | 51 | 52 | 82 | 96 | 1.9 |
| 419641 | 32 | 52 | 69 | 87 | 94 | 97 | 1.2 |
| 444661 | 45 | 59 | 66 | 85 | 91 | 95 | 0.8 |
| 419642 | 6 | 3 | 56 | 81 | 91 | 98 | 2.9 |
| 436665 | 40 | 43 | 70 | 73 | 84 | 89 | 1.2 |
| 436671 | 31 | 51 | 68 | 82 | 90 | 97 | 1.2 |
| 436689 | 24 | 37 | 59 | 74 | 89 | 98 | 1.9 |
| 437507 | 21 | 15 | 11 | 33 | 55 | 92 | 6.4 |
| 443139 | 31 | 36 | 37 | 56 | 76 | 97 | 2.6 |

ISIS 387916, ISIS 388241, ISIS 436684, ISIS 437168, ISIS 437175, ISIS 437441, ISIS 437507, ISIS 437527, ISIS 444578, ISIS 444584, ISIS 444591, and ISIS 444607 were further tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells were tested in a similar procedure as described above. The results are presented in Table 19 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 19 expressed in μM.

TABLE 19

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No. | 625.0 nM | 1250.0 nM | 2500.0 nM | 5000.0 nM | 10000.0 nM | 20000.0 nM | $IC_{50}$ |
|---|---|---|---|---|---|---|---|
| 387916 | 23 | 42 | 57 | 81 | 88 | 96 | 1.95 |
| 388241 | 6 | 12 | 37 | 43 | 62 | 84 | 5.32 |
| 437168 | 72 | 47 | 60 | 78 | 83 | 92 | 1.43 |
| 437175 | 27 | 48 | 36 | 56 | 68 | 78 | 3.58 |
| 437441 | 29 | 34 | 50 | 67 | 56 | 85 | 2.43 |
| 437507 | 18 | 29 | 18 | 33 | 45 | 66 | 6.12 |
| 437527 | 36 | 36 | 48 | 57 | 81 | 90 | 2.71 |
| 436684 | 0 | 12 | 24 | 29 | 36 | 49 | n.d. |
| 444578 | 34 | 40 | 65 | 74 | 82 | 87 | 1.70 |
| 444584 | 28 | 38 | 68 | 75 | 90 | 94 | 1.69 |
| 444591 | 25 | 45 | 55 | 74 | 85 | 94 | 1.84 |
| 444607 | 41 | 54 | 76 | 87 | 92 | 94 | 0.96 |

n.d. = $IC_{50}$ could not be measured for that compound

ISIS 387916, ISIS 388241, ISIS 444608, ISIS 444615, ISIS 444618, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, and ISIS 444661 were further tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells were tested in a similar procedure as described above. The results are presented in Table 20 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 20 expressed in μM.

TABLE 20

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No | 625.0 nM | 1250.0 nM | 2500.0 nM | 5000.0 nM | 10000.0 nM | 20000.0 nM | IC50 |
|---|---|---|---|---|---|---|---|
| 387916 | 35 | 44 | 68 | 74 | 90 | 96 | 1.35 |
| 388241 | 23 | 37 | 54 | 56 | 68 | 89 | 2.64 |
| 444608 | 43 | 50 | 64 | 83 | 90 | 95 | 1.07 |
| 444615 | 29 | 45 | 55 | 76 | 90 | 97 | 1.67 |
| 444618 | 30 | 34 | 57 | 73 | 89 | 95 | 1.66 |
| 444627 | 35 | 56 | 76 | 90 | 97 | 98 | 1.00 |
| 444652 | 32 | 55 | 66 | 55 | 92 | 98 | 1.23 |
| 444658 | 50 | 62 | 80 | 90 | 95 | 97 | 0.55 |
| 444659 | 31 | 56 | 68 | 86 | 95 | 97 | 1.17 |
| 444660 | 38 | 49 | 62 | 86 | 89 | 96 | 1.26 |
| 444661 | 41 | 50 | 75 | 68 | 95 | 97 | 0.95 |

ISIS 387916, ISIS 419627, ISIS 419628, ISIS 419629, ISIS 419630, ISIS 419636, ISIS 419637, ISIS 419640, ISIS 419641, and ISIS 419642 were further tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells at a density of 3,000 cells per well were transfected using lipofectin transfection reagent with 6.25 nM, 12.5 nM, 25 nM, 50 nM, 100 nM, or 200 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2686 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 21 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 21 expressed in nM.

TABLE 21

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No. | 6.25 nM | 12.5 nM | 25.0 nM | 50.0 nM | 100.0 nM | 200.0 nM | $IC_{50}$ |
|---|---|---|---|---|---|---|---|
| 387916 | 1 | 37 | 37 | 53 | 84 | 90 | 35 |
| 419627 | 0 | 9 | 18 | 45 | 58 | 72 | 75 |
| 419628 | 9 | 30 | 49 | 63 | 73 | 77 | 31 |
| 419629 | 9 | 16 | 40 | 56 | 80 | 85 | 36 |
| 419630 | 17 | 8 | 43 | 58 | 71 | 81 | 40 |
| 419636 | 23 | 25 | 38 | 55 | 72 | 78 | 37 |
| 419637 | 10 | 35 | 31 | 62 | 78 | 76 | 33 |
| 419640 | 3 | 28 | 39 | 59 | 74 | 87 | 36 |
| 419641 | 11 | 34 | 51 | 65 | 85 | 87 | 26 |
| 419642 | 25 | 30 | 49 | 65 | 85 | 88 | 24 |

ISIS 387916, ISIS 419641, and ISIS 436689 were further tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells at a density of 3,000 cells per well were transfected using LipofectAMINE2000 transfection reagent with 6.25 nM, 12.5 nM, 25 nM, 50 nM, 100 nM, or 200 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2686 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 22 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 22 expressed in nM.

TABLE 22

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No | 6.25 nM | 12.5 nM | 25 nM | 50 nM | 100 nM | 200 nM | $IC_{50}$ (nM) |
|---|---|---|---|---|---|---|---|
| 387916 | 0 | 50 | 31 | 68 | 83 | 90 | 47 |
| 419641 | 28 | 23 | 28 | 51 | 65 | 81 | 74 |
| 436689 | 16 | 30 | 29 | 48 | 67 | 83 | 69 |

ISIS 387916, ISIS 388241, ISIS 436665, ISIS 436671, and ISIS 436689 were further tested for their effect on rhesus monkey huntingtin mRNA in vitro. Cultured LLC-MK2 cells at a density of 3,000 cells per well were transfected using lipofectin transfection reagent with 4.6875 nM, 9.375 nM, 18.75 nM, 37.5 nM, 75 nM, or 150 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2686 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 23 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 23 expressed in nM.

TABLE 23

Dose dependent reduction of huntingtin mRNA in LLC-MK2 cells

| ISIS No. | 4.6875 nM | 9.375 nM | 18.75 nM | 37.5 nM | 75.0 nM | 150.0 nM | $IC_{50}$ (nM) |
|---|---|---|---|---|---|---|---|
| 387916 | 7 | 6 | 38 | 59 | 82 | 91 | 32 |
| 388241 | 0 | 0 | 5 | 35 | 62 | 81 | 60 |
| 436665 | 7 | 0 | 36 | 59 | 64 | 69 | 37 |
| 436671 | 21 | 7 | 35 | 59 | 80 | 86 | 31 |
| 436689 | 38 | 45 | 45 | 59 | 76 | 86 | 15 |

D. BACHD Transgenic Mouse Hepatocyes

Some of the antisense oligonucleotides described in Example 1 and targeted to a human huntingtin nucleic acid were tested for their effect on human huntingtin mRNA in vitro. Cultured BACHD mouse hepatocytes at a density of 10,000 cells per well were transfected using cytofectin transfection reagent with 7.4074 nM, 22.222 nM, 66.667 nM, or 200 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 24 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The data presented is the average of two experiments. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 24 expressed in nM.

TABLE 24

Dose dependent reduction of huntingtin mRNA in BACHD transgenic murine hepatocytes

| ISIS No. | 7.4074 nM | 22.222 nM | 66.667 nM | 200.00 nM | $IC_{50}$ (nM) |
|---|---|---|---|---|---|
| 387916 | 8 | 19 | 58 | 89 | 40 |
| 419640 | 15 | 30 | 64 | 93 | 33 |
| 419641 | 20 | 35 | 73 | 97 | 31 |
| 419642 | 3 | 29 | 70 | 96 | 43 |

ISIS 387916, ISIS 388241, and ISIS 419641 were further tested for their effect on human huntingtin mRNA in vitro. Cultured BACHD mouse hepatocytes at a density of 10,000 cells per well were transfected using cytofectin transfection reagent with 12.5 nM, 25 nM, 50 nM, 100 nM or 200 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Human primer probe set RTS2617 was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 25 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 25 expressed in nM.

TABLE 25

| Dose dependent reduction of huntingtin mRNA in BACHD transgenic murine hepatocytes | | | | | | |
|---|---|---|---|---|---|---|
| ISIS No. | 12.5 nM | 25 nM | 50 Nm | 100 nM | 200 nM | $IC_{50}$ (nM) |
| 387916 | 0 | 37 | 51 | 78 | 91 | 51 |
| 388241 | 0 | 10 | 45 | 70 | 92 | 68 |
| 419641 | 17 | 38 | 70 | 88 | 96 | 34 |

ISIS 387916, ISIS 388241, ISIS 419641, ISIS 436665, ISIS 436671, and ISIS 436689 were further tested for their effect on human huntingtin mRNA in vitro. Cultured BACHD mouse hepatocytes were tested in an identical manner as described above. The results are presented in Table 26 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 26 expressed in nM.

TABLE 26

| Dose dependent reduction of huntingtin mRNA in BACHD transgenic murine hepatocytes | | | | | | |
|---|---|---|---|---|---|---|
| ISIS No. | 12.5 nM | 25 nM | 50 nM | 100 nM | 200 nM | $IC_{50}$ (nM) |
| 387916 | 19 | 48 | 64 | 86 | 93 | 32 |
| 388241 | 20 | 34 | 54 | 81 | 93 | 38 |
| 419641 | 38 | 54 | 70 | 85 | 95 | 21 |
| 436665 | 32 | 40 | 67 | 84 | 93 | 29 |
| 436671 | 32 | 42 | 58 | 78 | 91 | 32 |
| 436689 | 35 | 44 | 70 | 88 | 96 | 25 |

ISIS 387916, ISIS 419640, ISIS 419641, and ISIS 419642 were further tested for their effect on mouse huntingtin mRNA in vitro. Cultured BACHD mouse hepatocytes at a density of 20,000 cells per well were transfected using cytofectin transfection reagent with 6.667 nM, 20 nM, 60 nM, or 180 nM of antisense oligonucleotide. After a treatment period of approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA levels were measured by quantitative real-time PCR. Murine primer probe set RTS2633 (forward sequence CAGAGCTGGTCAACCGTATCC, designated herein as SEQ ID NO: 43; reverse sequence GGCTTAAA-CAGGGAGCCAAAA, designated herein as SEQ ID NO: 44; probe sequence ACTTCATGATGAGCTCGGAGT-TCAACX, designated herein as SEQ ID NO: 45) was used to measure mRNA levels. Huntingtin mRNA levels were adjusted according to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 27 as percent inhibition of huntingtin mRNA, relative to untreated control cells, and demonstrate antisense oligonucleotide-mediated dose-dependent reduction of huntingtin mRNA levels. The $IC_{50}$ of each antisense oligonucleotide is also presented in Table 27 expressed in nM.

TABLE 27

| Dose dependent reduction of huntingtin mRNA in BACHD transgenic murine hepatocytes | | | | | |
|---|---|---|---|---|---|
| ISIS No. | 6.667 nM | 20 nM | 60 nM | 180 nM | $IC_{50}$ (nM) |
| 387916 | 15 | 15 | 68 | 94 | 37 |
| 419640 | 4 | 39 | 73 | 94 | 32 |
| 419641 | 16 | 45 | 81 | 96 | 24 |
| 419642 | 23 | 39 | 75 | 93 | 25 |

## Example 3

### Systemic Administration of Antisense Oligonucleotides Against Huntingtin mRNA in BACHD Mice

Of the about seventeen hundred newly designed antisense compounds, sixty six compounds were selected based on in vitro potency compared to ISIS 387916 for testing in systemic tolerability screens.

BACHD mice were treated with ISIS oligonucleotides and evaluated for changes in the levels of various metabolic markers as well as inhibition of huntingtin mRNA in the liver. Antisense oligonucleotides which caused adverse changes in body weight, organ weight or in the levels of metabolic markers were deemed unsuitable for utilization in further studies.

Study 1.

Treatment

Nineteen groups of four BACHD mice each were injected intraperitoneally with 12.5 mg/kg of ISIS 387916, ISIS 388241, ISIS 419629, ISIS 419637, ISIS 436684, ISIS 444578, ISIS 444584, ISIS 444591, ISIS 444607, ISIS 444608, ISIS 444615, ISIS 444618, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, ISIS 444661, or ISIS 444663 twice a week for 2 weeks. A control group of four mice was injected intraperitoneally with PBS twice a week for 2 weeks. Two days after the last dose, the mice were anaesthetized with isoflurane and exsanguinated for plasma collection, after which cervical dislocation was performed and organs collected.

RNA Analysis

RNA was extracted from liver tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin levels were measured using the mouse primer probe set RTS2633. Results are presented in Tables 28 and 29 and were calculated as percent inhibition of human and murine huntingtin expression levels respectively, relative to the PBS control. All the antisense oligonucleotides effect significant inhibition of human huntingtin mRNA levels. ISIS 388241 has more than three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control.

TABLE 28

| Percent inhibition of human huntingtin mRNA in BACHD mice | |
|---|---|
| ISIS No. | % inhibition |
| 387916 | 82 |
| 388241 | 52 |
| 419629 | 80 |
| 419637 | 83 |

TABLE 28-continued

| Percent inhibition of human huntingtin mRNA in BACHD mice | |
|---|---|
| ISIS No. | % inhibition |
| 436684 | 55 |
| 444578 | 70 |
| 444584 | 62 |
| 444591 | 54 |
| 444607 | 76 |
| 444608 | 61 |
| 444615 | 89 |
| 444618 | 91 |
| 444627 | 92 |
| 444652 | 79 |
| 444658 | 62 |
| 444659 | 74 |
| 444660 | 66 |
| 444661 | 72 |
| 444663 | 77 |

TABLE 29

| Percent inhibition of murine huntingtin mRNA in BACHD mice | |
|---|---|
| ISIS No. | % inhibition |
| 387916 | 77 |
| 419629 | 75 |
| 419637 | 87 |
| 436684 | 32 |
| 444578 | 64 |
| 444584 | 20 |
| 444591 | 32 |
| 444607 | 76 |
| 444608 | 66 |
| 444615 | 60 |
| 444618 | 88 |
| 444627 | 58 |
| 444652 | 66 |
| 444658 | 53 |
| 444659 | 62 |
| 444660 | 47 |
| 444661 | 67 |
| 444663 | 60 |

Organ Weight Measurements

Liver, spleen and kidney weights were measured at the end of the study, and are presented in Table 30 as a percent of the saline control normalized to body weight.

TABLE 30

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | |
|---|---|---|---|
| ISIS No. | Liver | Spleen | Kidney |
| 387916 | −5 | −13 | +6 |
| 388241 | −1 | +14 | −5 |
| 419629 | +5 | +13 | −12 |
| 419637 | −6 | −17 | −25 |
| 436684 | −2 | −3 | +6 |
| 444578 | +11 | +18 | +1 |
| 444584 | +8 | +54 | +1 |
| 444591 | +4 | −4 | −3 |
| 444607 | +3 | +22 | −8 |
| 444608 | +6 | +18 | −3 |
| 444615 | +6 | +1 | +3 |
| 444618 | +11 | +0 | −2 |
| 444627 | +3 | −14 | +14 |
| 444652 | −11 | −4 | −18 |

TABLE 30-continued

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | |
|---|---|---|---|
| ISIS No. | Liver | Spleen | Kidney |
| 444658 | −1 | 0 | −16 |
| 444659 | +1 | +15 | −2 |
| 444660 | −5 | +4 | −6 |
| 444661 | −1 | +7 | −1 |
| 444663 | +7 | +10 | +8 |

Evaluation of Liver Function

To evaluate the impact of ISIS oligonucleotides on the hepatic function of the mice described above, plasma concentrations of transaminases were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Measurements of alanine transaminase (ALT) and aspartate transaminase (AST) are expressed in IU/L and the results are presented in Table 31.

TABLE 31

| Effect of antisense oligonucleotide treatment on markers of liver function | | |
|---|---|---|
| | ALT | AST |
| PBS | 40 | 69 |
| 387916 | 69 | 84 |
| 388241 | 42 | 76 |
| 419629 | 51 | 71 |
| 419637 | 59 | 86 |
| 436684 | 60 | 87 |
| 444578 | 62 | 93 |
| 444584 | 48 | 76 |
| 444591 | 39 | 53 |
| 444607 | 51 | 111 |
| 444608 | 48 | 75 |
| 444615 | 74 | 95 |
| 444618 | 687 | 908 |
| 444627 | 105 | 127 |
| 444652 | 54 | 64 |
| 444658 | 46 | 59 |
| 444659 | 90 | 138 |
| 444660 | 34 | 64 |
| 444661 | 49 | 99 |
| 444663 | 90 | 164 |

Study 2

Treatment

Fourteen groups of four BACHD mice each were injected intraperitoneally with 12.5 mg/kg or 50 mg/kg of ISIS 419581, ISIS 419602, ISIS 419628, ISIS 419629, ISIS 419640, ISIS 419641, or ISIS 419642 twice a week for 2 weeks. A group of four BACHD mice was injected intraperitoneally with 12.5 mg/kg of ISIS 387916 twice a week for 2 weeks. A control group of four mice was injected intraperitoneally with PBS twice a week for 2 weeks. Two days after the last dose, the mice were anaesthetized with isoflurane and exsanguinated for plasma collection, after which cervical dislocation was performed and organs collected.

RNA Analysis

RNA was extracted from liver tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin levels were measured using the mouse primer probe set RTS2633. Results are presented in Tables 32 and 33 and were calculated as percent inhibition of human and murine huntingtin expression levels respectively, relative to the PBS control.

TABLE 32

| Percent inhibition of human huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 387916 | 12.5 | 71 |
| 419581 | 12.5 | 54 |
| | 50 | 68 |
| 419602 | 12.5 | 72 |
| | 50 | 77 |
| 419628 | 12.5 | 65 |
| | 50 | 76 |
| 419629 | 12.5 | 87 |
| | 50 | 93 |
| 419640 | 12.5 | 69 |
| | 50 | 79 |
| 419641 | 12.5 | 61 |
| | 50 | 80 |
| 419642 | 12.5 | 76 |
| | 50 | 83 |

TABLE 33

| Percent inhibition of murine huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 387916 | 12.5 | 70 |
| 419581 | 12.5 | 42 |
| | 50 | 86 |
| 419602 | 12.5 | 77 |
| | 50 | 85 |
| 419628 | 12.5 | 67 |
| | 50 | 86 |
| 419629 | 12.5 | 90 |
| | 50 | 93 |
| 419640 | 12.5 | 63 |
| | 50 | 84 |
| 419641 | 12.5 | 52 |
| | 50 | 81 |
| 419642 | 12.5 | 56 |
| | 50 | 83 |

Organ Weight Measurements

Liver, spleen and kidney weights were measured at the end of the study, and are presented in Table 34 as a percent of the saline control normalized to body weight.

TABLE 34

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| ISIS No. | Dose (mg/kg) | Liver | Spleen | Kidney |
| 387916 | 12.5 | −9 | 3 | −4 |
| 419581 | 12.5 | −2 | −6 | −1 |
| | 50 | 14 | −1 | −11 |
| 419602 | 12.5 | 10 | 1 | −2 |
| | 50 | 28 | 9 | −3 |
| 419628 | 12.5 | −2 | −7 | −2 |
| | 50 | −3 | 7 | −9 |
| 419629 | 12.5 | −7 | −5 | −10 |
| | 50 | 16 | 0 | −8 |
| 419640 | 12.5 | −5 | −2 | −8 |
| | 50 | 1 | −20 | −4 |
| 419641 | 12.5 | −7 | −10 | −11 |
| | 50 | −2 | −13 | −9 |
| 419642 | 12.5 | −11 | −21 | −19 |
| | 50 | −1 | −8 | −9 |

Evaluation of Liver Function

To evaluate the impact of ISIS oligonucleotides on the hepatic function of the mice described above, plasma concentrations of transaminases were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Measurements of ALT and AST are expressed in IU/Land the results are presented in Table 35.

TABLE 35

| Effect of antisense oligonucleotide treatment on markers of liver function | | | |
|---|---|---|---|
| | Dose (mg/kg) | ALT | AST |
| PBS | | 44 | 80 |
| 387916 | 12.5 | 44 | 75 |
| 419581 | 12.5 | 56 | 101 |
| | 50 | 390 | 281 |
| 419602 | 12.5 | 86 | 108 |
| | 50 | 240 | 229 |
| 419628 | 12.5 | 52 | 110 |
| | 50 | 51 | 73 |
| 419629 | 12.5 | 104 | 118 |
| | 50 | 1262 | 1150 |
| 419640 | 12.5 | 36 | 65 |
| | 50 | 38 | 55 |
| 419641 | 12.5 | 56 | 103 |
| | 50 | 57 | 172 |
| 419642 | 12.5 | 40 | 64 |
| | 50 | 47 | 101 |

Study 3

Treatment

Eighteen groups of four BACHD mice each were injected intraperitoneally with 12.5 mg/kg or 50 mg/kg of ISIS 388250, ISIS 388251, ISIS 388263, ISIS 388264, ISIS 419641, ISIS 436645, ISIS 436649, ISIS 436668, or ISIS 436689 twice a week for 2 weeks. A group of four BACHD mice was injected intraperitoneally with 12.5 mg/kg of ISIS 388241 twice a week for 2 weeks. A control group of four mice was injected intraperitoneally with PBS twice a week for 2 weeks. Two days after the last dose, the mice were anaesthetized with isoflurane and exsanguinated for plasma collection, after which cervical dislocation was performed and organs collected.

RNA Analysis

RNA was extracted from liver tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin levels were measured using the mouse primer probe set RTS2633. Results are presented in Tables 36 and 37 and were calculated as percent inhibition of human and murine huntingtin expression levels respectively, relative to the PBS control. All the antisense oligonucleotides effect significant inhibition of human huntingtin mRNA levels. ISIS 388241, ISIS 388250, ISIS 388251, ISIS 388263, ISIS 388264, and ISIS 436645 have more than three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control. ISIS 436649 and ISIS 436689 have three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control.

TABLE 36

| Percent inhibition of human huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 388241 | 12.5 | 32 |
| 388250 | 12.5 | 21 |
| | 50 | 45 |
| 388251 | 12.5 | 30 |
| | 50 | 34 |
| 388263 | 12.5 | 29 |
| | 50 | 35 |
| 388264 | 12.5 | 35 |
| | 50 | 42 |
| 419641 | 12.5 | 71 |
| | 50 | 73 |
| 436645 | 12.5 | 43 |
| | 50 | 48 |
| 436649 | 12.5 | 40 |
| | 50 | 38 |
| 436668 | 12.5 | 45 |
| | 50 | 69 |
| 436689 | 12.5 | 62 |
| | 50 | 78 |

TABLE 37

| Percent inhibition of murine huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 419641 | 12.5 | 68 |
| | 50 | 77 |
| 436668 | 12.5 | 41 |
| | 50 | 62 |

Organ Weight Measurements

Liver, spleen and kidney weights were measured at the end of the study, and are presented in Table 38 as a percent of the saline control normalized to body weight. Mice treated with ISIS 388263 and ISIS 436645 suffered increases in liver weight at the 50 mg/kg dose compared to the PBS control.

TABLE 38

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| ISIS No. | Dose (mg/kg) | Liver | Spleen | Kidney |
| 388241 | 12.5 | 1 | 6 | 9 |
| 388250 | 12.5 | 2 | 1 | −2 |
| | 50 | 1 | 30 | 3 |
| 388251 | 12.5 | 4 | −8 | 1 |
| | 50 | 19 | 19 | 2 |
| 388263 | 12.5 | 4 | 8 | 9 |
| | 50 | 23 | 52 | 1 |
| 388264 | 12.5 | 2 | −2 | 3 |
| | 50 | 12 | 9 | 6 |
| 419641 | 12.5 | −1 | −9 | 3 |
| | 50 | 2 | −4 | 3 |
| 436645 | 12.5 | 8 | 6 | 5 |
| | 50 | 26 | 25 | 9 |
| 436649 | 12.5 | 1 | 0 | 6 |
| | 50 | 0 | 1 | 3 |
| 436668 | 12.5 | 1 | 5 | 10 |
| | 50 | −2 | 3 | 11 |
| 436689 | 12.5 | −3 | −5 | 4 |
| | 50 | 6 | 11 | 5 |

Evaluation of Liver Function

To evaluate the impact of ISIS oligonucleotides on the hepatic function of the mice described above, plasma concentrations of transaminases were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Measurements of alanine transaminase (ALT) and aspartate transaminase (AST) are expressed in IU/L and the results are presented in Table 39.

TABLE 39

| Effect of antisense oligonucleotide treatment on markers of liver function | | | |
|---|---|---|---|
| | Dose (mg/kg) | ALT | AST |
| PBS | | 43 | 76 |
| 388241 | 12.5 | 43 | 88 |
| 388250 | 12.5 | 37 | 55 |
| | 50 | 44 | 89 |
| 388251 | 12.5 | 42 | 98 |
| | 50 | 67 | 91 |
| 388263 | 12.5 | 51 | 90 |
| | 50 | 55 | 93 |
| 388264 | 12.5 | 31 | 59 |
| | 50 | 65 | 90 |
| 419641 | 12.5 | 39 | 70 |
| | 50 | 42 | 83 |
| 436645 | 12.5 | 43 | 82 |
| | 50 | 179 | 143 |
| 436649 | 12.5 | 35 | 47 |
| | 50 | 38 | 76 |
| 436668 | 12.5 | 36 | 73 |
| | 50 | 28 | 57 |
| 436689 | 12.5 | 31 | 52 |
| | 50 | 49 | 164 |

Study 4

Treatment

Eighteen groups of four BACHD mice each were injected intraperitoneally with 12.5 mg/kg or 50 mg/kg of ISIS 388241, ISIS 437123, ISIS 437132, ISIS 437140, ISIS 437442, ISIS 437446, ISIS 437477, ISIS 437478, or ISIS 437490 twice a week for 2 weeks. A group of four BACHD mice was injected intraperitoneally with 12.5 mg/kg of ISIS 387916 twice a week for 2 weeks. A control group of four mice was injected intraperitoneally with PBS twice a week for 2 weeks. Two days after the last dose, the mice were anaesthetized with isoflurane and exsanguinated for plasma collection, after which cervical dislocation was performed and organs collected.

RNA Analysis

RNA was extracted from liver tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin levels were measured using the mouse primer probe set RTS2633. Results are presented in Tables 40 and 41 and were calculated as percent inhibition of human and murine huntingtin expression levels respectively, relative to the PBS control. ISIS 388241 and ISIS 437490 have more than three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control. ISIS 437132 has three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control. ISIS 437123 and ISIS 437140 have two mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and do not show significant inhibition of murine mRNA levels compared to the control.

TABLE 40

| Percent inhibition of human huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 387916 | 12.5 | 51 |
| 388241 | 12.5 | 47 |
| | 50 | 67 |
| 437123 | 12.5 | 0 |
| | 50 | 21 |
| 437132 | 12.5 | 31 |
| | 50 | 33 |
| 437140 | 12.5 | 7 |
| | 50 | 32 |
| 437442 | 12.5 | 42 |
| | 50 | 85 |
| 437446 | 12.5 | 39 |
| | 50 | 70 |
| 437477 | 12.5 | 52 |
| | 50 | 75 |
| 437478 | 12.5 | 54 |
| | 50 | 78 |
| 437490 | 12.5 | 42 |
| | 50 | 44 |

TABLE 41

| Percent inhibition of murine huntingtin mRNA in BACHD mice | | |
|---|---|---|
| ISIS No. | Dose (mg/kg) | % inhibition |
| 387916 | 12.5 | 48 |
| 437442 | 12.5 | 27 |
| | 50 | 76 |
| 437446 | 12.5 | 38 |
| | 50 | 71 |
| 437477 | 12.5 | 63 |
| | 50 | 87 |
| 437478 | 12.5 | 60 |
| | 50 | 89 |

Organ Weight Measurements

Liver, spleen and kidney weights were measured at the end of the study, and are presented in Table 42 as a percent of the saline control normalized to body weight.

TABLE 42

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| ISIS No. | Dose (mg/kg) | Liver | Spleen | Kidney |
| 387916 | 12.5 | 1 | 6 | 12 |
| 388241 | 12.5 | −3 | 16 | −2 |
| | 50 | −6 | 10 | 0 |
| 437123 | 12.5 | −4 | 0 | 4 |
| | 50 | 4 | 0 | −4 |
| 437132 | 12.5 | −2 | −3 | −5 |
| | 50 | 2 | −6 | −2 |
| 437140 | 12.5 | −4 | 11 | −3 |
| | 50 | 4 | 5 | −5 |
| 437442 | 12.5 | −10 | 9 | 3 |
| | 50 | −3 | −20 | −10 |
| 437446 | 12.5 | −6 | 7 | 2 |
| | 50 | −4 | 1 | −1 |
| 437477 | 12.5 | 1 | −2 | 0 |
| | 50 | 25 | −9 | −6 |
| 437478 | 12.5 | −7 | −4 | −9 |
| | 50 | 22 | 4 | 3 |

TABLE 42-continued

| Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| ISIS No. | Dose (mg/kg) | Liver | Spleen | Kidney |
| 437490 | 12.5 | −5 | 0 | −5 |
| | 50 | −7 | 3 | −9 |

Evaluation of Liver Function

To evaluate the impact of ISIS oligonucleotides on the hepatic function of the mice described above, plasma concentrations of transaminases were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Measurements of alanine transaminase (ALT) and aspartate transaminase (AST) are expressed in IU/L and the results are presented in Table 43.

TABLE 43

| Effect of antisense oligonucleotide treatment on markers of liver function | | | |
|---|---|---|---|
| | Dose (mg/kg) | ALT | AST |
| PBS | | 32 | 58 |
| 387916 | 12.5 | 40 | 122 |
| 388241 | 12.5 | 39 | 93 |
| | 50 | 28 | 62 |
| 437123 | 12.5 | 38 | 88 |
| | 50 | 34 | 66 |
| 437132 | 12.5 | 34 | 52 |
| | 50 | 30 | 52 |
| 437140 | 12.5 | 30 | 62 |
| | 50 | 40 | 63 |
| 437442 | 12.5 | 40 | 106 |
| | 50 | 63 | 119 |
| 437446 | 12.5 | 35 | 119 |
| | 50 | 35 | 89 |
| 437477 | 12.5 | 39 | 68 |
| | 50 | 52 | 162 |
| 437478 | 12.5 | 37 | 53 |
| | 50 | 55 | 71 |
| 437490 | 12.5 | 48 | 71 |
| | 50 | 34 | 59 |

Study 5

Treatment

Eleven groups of four BACHD mice each were injected intraperitoneally with 12.5 mg/kg of ISIS 388241, ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436671, ISIS 436689, ISIS 437507, ISIS 443139, ISIS 444591, or ISIS 444661 twice a week for 2 weeks. A control group of four mice was injected intraperitoneally with phosphate buffered saline (PBS) twice a week for 2 weeks. Two days after the last dose, the mice were anaesthetized with isoflurane and exsanguinated for plasma collection, after which cervical dislocation was performed and organs collected.

RNA Analysis

RNA was extracted from liver tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin levels were measured using the mouse primer probe set RTS2633. Results are presented in Tables 44 and 45 and were calculated as percent inhibition of human and murine huntingtin expression levels respectively, relative to the PBS control. All the antisense oligonucleotides effect significant inhibition of human huntingtin mRNA levels. ISIS 388241, ISIS 437507, and ISIS 443139 have more than three mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore do not show significant inhibition of murine mRNA levels compared to the control. ISIS 436689 has 3 mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and does not show significant inhibition of murine mRNA levels compared to the control.

TABLE 44

Percent inhibition of human huntingtin mRNA in BACHD mice

| ISIS No. | % inhibition |
|---|---|
| 388241 | 53 |
| 419640 | 34 |
| 419641 | 63 |
| 419642 | 55 |
| 436665 | 63 |
| 436671 | 66 |
| 436689 | 57 |
| 437507 | 54 |
| 443139 | 39 |
| 444591 | 48 |
| 444661 | 50 |

TABLE 45

Percent inhibition of murine huntingtin mRNA in BACHD mice

| ISIS No. | % inhibition |
|---|---|
| 419640 | 24 |
| 419641 | 51 |
| 419642 | 34 |
| 436665 | 49 |
| 436671 | 63 |
| 444591 | 41 |
| 444661 | 46 |

Body Weight and Organ Weight Measurements

The body weights of the mice were measured at the onset of the study and subsequently twice a week. The body weights of the mice are presented in Table 46 and are expressed as a percent change over the weights taken at the start of the study. The results indicate that treatment with these oligonucleotides did not cause any adverse change in body weight of the mice throughout the study.

TABLE 46

Percent change in body weight of BACHD mice after antisense oligonucleotide treatment

| | day 4 | day 7 | day 10 | day 12 |
|---|---|---|---|---|
| PBS | −3 | 0 | +2 | +1 |
| ISIS 388241 | −2 | −1 | −1 | +1 |
| ISIS 419640 | +1 | 0 | +3 | +4 |
| ISIS 419641 | +1 | +1 | +2 | 0 |
| ISIS 419642 | −3 | −2 | +1 | −5 |
| ISIS 436665 | +1 | +4 | +5 | +1 |
| ISIS 436671 | +1 | +2 | +5 | +4 |
| ISIS 436689 | +1 | +3 | 0 | −1 |
| ISIS 437507 | −1 | −2 | +2 | −2 |
| ISIS 443139 | −2 | +6 | +4 | +1 |
| ISIS 444591 | −1 | +1 | +2 | 0 |
| ISIS 444661 | +1 | +3 | +2 | 0 |

Liver, spleen and kidney weights were measured at the end of the study, and are presented in Table 47 as a percent of the saline control normalized to body weight.

TABLE 47

Percent change in organ weight of BACHD mice after antisense oligonucleotide treatment

| ISIS No. | Liver | Spleen | Kidney |
|---|---|---|---|
| 388241 | +2 | +13 | −7 |
| 419640 | −2 | +12 | −12 |
| 419641 | +4 | +3 | −13 |
| 419642 | +5 | +19 | −8 |
| 436665 | −3 | +3 | −13 |
| 436671 | 0 | +1 | −18 |
| 436689 | −6 | −10 | −12 |
| 437507 | −5 | −5 | −14 |
| 443139 | −2 | −9 | −13 |
| 444591 | −2 | −10 | −12 |
| 444661 | 0 | −16 | −12 |

Evaluation of Liver Function

To evaluate the impact of ISIS oligonucleotides on the hepatic function of the mice described above, plasma concentrations of transaminases were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Measurements of ALT and AST are expressed in IU/L. Plasma levels of bilirubin and albumin were also measured using the same clinical chemistry analyzer and expressed in g/dL. The results are presented in Table 48.

TABLE 48

Effect of antisense oligonucleotide treatment on markers of liver function

| | ALT | AST | Bilirubin | Albumin |
|---|---|---|---|---|
| PBS | 42.5 | 86.5 | 0.2 | 3.1 |
| ISIS 388241 | 39.3 | 54.5 | 0.3 | 3.0 |
| ISIS 419640 | 36.8 | 85.8 | 0.2 | 2.9 |
| ISIS 419641 | 50.0 | 71.8 | 0.2 | 3.0 |
| ISIS 419642 | 42.8 | 77.0 | 0.1 | 3.0 |
| ISIS 436665 | 51.5 | 123.0 | 0.2 | 3.0 |
| ISIS 436671 | 52.0 | 71.0 | 0.1 | 3.0 |
| ISIS 436689 | 38.3 | 75.3 | 0.2 | 3.1 |
| ISIS 437507 | 37.0 | 77.5 | 0.1 | 3.0 |
| ISIS 443139 | 41.3 | 124.8 | 0.2 | 3.0 |
| ISIS 444591 | 46.5 | 61.3 | 0.2 | 3.0 |
| ISIS 444661 | 67.5 | 109.8 | 0.2 | 3.1 |

Measurement of Kidney Function

To evaluate the impact of ISIS oligonucleotides on the kidney function of mice described above, plasma concentrations of blood urea nitrogen (BUN) and creatinine were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Results are presented in Table 49 expressed in mg/dL.

TABLE 49

Effect of antisense oligonucleotide treatment on markers of kidney function

| | BUN | Creatinine |
|---|---|---|
| PBS | 24.0 | 0.17 |
| ISIS 388241 | 22.6 | 0.17 |
| ISIS 419640 | 21.4 | 0.16 |
| ISIS 419641 | 19.9 | 0.16 |
| ISIS 419642 | 23.6 | 0.18 |
| ISIS 436665 | 20.2 | 0.17 |
| ISIS 436671 | 22.6 | 0.17 |
| ISIS 436689 | 19.2 | 0.18 |
| ISIS 437507 | 19.9 | 0.16 |
| ISIS 443139 | 23.3 | 0.16 |

TABLE 49-continued

Effect of antisense oligonucleotide treatment on markers of kidney function

| | BUN | Creatinine |
|---|---|---|
| ISIS 444591 | 23.5 | 0.18 |
| ISIS 444661 | 25.4 | 0.18 |

Measurement of Other Metabolic Parameters

To evaluate the impact of ISIS oligonucleotides on other metabolic functions in mice described above, plasma concentrations of glucose, cholesterol and triglycerides were measured using an automated clinical chemistry analyzer (Hitachi Olympus AU400e, Melville, N.Y.). Results are presented in Table 50 expressed in mg/dL and demonstrate that treatment with these oligonucleotides did not cause any adverse changes in the levels of these metabolic markers between the control and treatment groups.

TABLE 50

Effect of antisense oligonucleotide treatment on metabolic markers

| | Glucose | Cholesterol | Triglycerides |
|---|---|---|---|
| PBS | 198 | 142 | 225 |
| ISIS 388241 | 197 | 133 | 185 |
| ISIS 419640 | 198 | 132 | 189 |
| ISIS 419641 | 188 | 140 | 219 |
| ISIS 419642 | 184 | 128 | 192 |
| ISIS 436665 | 199 | 134 | 152 |
| ISIS 436671 | 196 | 148 | 174 |
| ISIS 436689 | 194 | 132 | 174 |
| ISIS 437507 | 198 | 139 | 155 |
| ISIS 443139 | 178 | 122 | 239 |
| ISIS 444591 | 202 | 145 | 263 |
| ISIS 444661 | 180 | 140 | 247 |

## Example 4

### Bolus Administration of Antisense Oligonucleotides Against Huntingtin mRNA to the Striatum of BACHD Mice

BACHD mice were treated with ISIS oligonucleotides via bolus administration to a defined mouse brain area, the striatum, for the purpose of screening the activity of the oligonucleotides in brain tissue against human and mouse huntingtin mRNA expression.

Treatment and Surgery

Groups of four BACHD mice each were administered with ISIS 388241, ISIS 419628, ISIS 419637, ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436671, ISIS 436684, ISIS 436689, ISIS 436754, ISIS 437168, ISIS 437175, ISIS 437441, ISIS 437442, ISIS 437507, ISIS 437527, ISIS 443139, ISIS 444578, ISIS 444584, ISIS 444591, ISIS 444607, ISIS 444608, ISIS 444615, ISIS 444618, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, ISIS 444661 or ISIS 444663 delivered as a single bolus injection at 3 μg, 10 μg or 25 μg concentrations into the striatum.

A control group of 4 BACHD mice were similarly treated with PBS. ISIS 388241 was administered in seven groups of 4 mice each and the results presented are the average of the data derived from the 28 mice. ISIS 419628 was administered in 2 groups of 4 BACHD mice each and the results presented are the average of the data derived from the 8 mice. Seven days after the bolus administration, the mice were euthanized using isoflurane and the organs were removed. The animals were decapitated and the brain was removed for dissection of the striatal tissue.

RNA Analysis

RNA was extracted from striatal tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin mRNA levels were measured using the murine primer probe set RTS2633. The results for human huntingtin mRNA levels are presented in Table 51 and are expressed as percent inhibition compared to the PBS control group. All the antisense oligonucleotides effect dose-dependent inhibition of human huntingtin mRNA levels. The results for murine huntingtin mRNA levels are presented in Table 52 and are expressed as percent inhibition compared to the PBS control group.

The effective doses ($ED_{50}$) of each oligonucleotide for human huntingtin mRNA and mouse huntingtin mRNA were calculated by plotting the concentrations of oligonucleotides used versus the percent inhibition of huntingtin mRNA expression levels of either species and noting the concentrations at which 50% inhibition of huntingtin mRNA expression was achieved for each species compared to the corresponding controls. The $ED_{50}$ (μg) for each antisense oligonucleotide is also presented in Tables 51 and 52 for human and murine huntingtin mRNA respectively.

ISIS 388241, ISIS 436684, ISIS 436754, ISIS 437175, ISIS 437507, ISIS 443139, and ISIS 444584 are each mismatched by 8 base pairs or more with murine huntingtin mRNA (SEQ ID NO: 3) and therefore do not show significant inhibition of murine mRNA levels compared to the control. ISIS 437168 and ISIS 437441 have 2 mismatches each with the murine huntingtin mRNA (SEQ ID NO: 3) and do not show significant inhibition of murine mRNA levels compared to the control. ISIS 436689 has 3 mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and does not show significant inhibition of murine mRNA levels compared to the control.

TABLE 51

Percent inhibition of human huntingtin mRNA levels in vivo and $ED_{50}$ of the antisense oligonucleotides

| ISIS No. | 3 mg | 10 mg | 25 mg | $ED_{50}$ |
|---|---|---|---|---|
| 388241 | 33 | 55 | 68 | 7.4 |
| 419628 | 49 | 58 | 83 | 5.1 |
| 419637 | 40 | 62 | 79 | 6.1 |
| 419640 | 52 | 64 | 77 | 4.8 |
| 419641 | 71 | 77 | 89 | 2.2 |
| 419642 | 67 | 70 | 83 | 3.0 |
| 436665 | 52 | 71 | 60 | 5.8 |
| 436671 | 68 | 80 | 84 | 2.4 |
| 436684 | 2 | 18 | 37 | 36.9 |
| 436689 | 27 | 63 | 81 | 7.0 |
| 436754 | 31 | 54 | 61 | 10.5 |
| 437168 | 2 | 49 | 60 | 15.2 |
| 437175 | 0 | 53 | 64 | 12.9 |
| 437441 | 3 | 32 | 38 | 35.3 |
| 437442 | 38 | 50 | 56 | 11.9 |
| 437507 | 38 | 59 | 79 | 6.6 |
| 437527 | 37 | 47 | 59 | 11.9 |
| 443139 | 39 | 61 | 70 | 6.7 |
| 444578 | 51 | 66 | 75 | 4.6 |
| 444584 | 30 | 63 | 71 | 7.8 |
| 444591 | 60 | 54 | 70 | 5.6 |
| 444607 | 57 | 69 | 75 | 3.2 |
| 444608 | 67 | 68 | 82 | 3.1 |
| 444615 | 47 | 55 | 91 | 5.2 |
| 444618 | 57 | 64 | 83 | 4.0 |

TABLE 51-continued

| Percent inhibition of human huntingtin mRNA levels in vivo and $ED_{50}$ of the antisense oligonucleotides | | | | |
|---|---|---|---|---|
| ISIS No. | 3 mg | 10 mg | 25 mg | $ED_{50}$ |
| 444627 | 47 | 70 | 61 | 5.0 |
| 444652 | 36 | 62 | 66 | 7.8 |
| 444658 | 60 | 66 | 79 | 3.6 |
| 444659 | 61 | 67 | 84 | 3.4 |
| 444660 | 55 | 62 | 66 | 4.2 |
| 444661 | 48 | 57 | 70 | 6.4 |
| 444663 | 42 | 60 | 80 | 5.5 |

TABLE 52

| Percent inhibition of murine huntingtin mRNA levels in vivo and $ED_{50}$ of the antisense oligonucleotides | | | | |
|---|---|---|---|---|
| ISIS No. | 3 mg | 10 mg | 25 mg | $ED_{50}$ |
| 419628 | 50 | 55 | 83 | 5.1 |
| 419637 | 63 | 79 | 86 | 2.6 |
| 419640 | 51 | 60 | 86 | 4.9 |
| 419641 | 65 | 80 | 87 | 2.7 |
| 419642 | 69 | 73 | 88 | 2.5 |
| 436665 | 68 | 82 | 66 | 2.7 |
| 436671 | 75 | 87 | 90 | 2 |
| 437442 | 30 | 53 | 82 | 9 |
| 437527 | 67 | 73 | 90 | 2.7 |
| 444578 | 50 | 65 | 74 | 4.9 |
| 444591 | 69 | 69 | 81 | 2.8 |
| 444607 | 57 | 70 | 75 | 3.8 |
| 444608 | 70 | 72 | 90 | 2.5 |
| 444615 | 30 | 37 | 88 | 9.5 |
| 444618 | 66 | 71 | 90 | 2.8 |
| 444627 | 41 | 60 | 57 | 8.8 |
| 444652 | 47 | 62 | 66 | 4.7 |
| 444658 | 60 | 62 | 85 | 3.9 |
| 444659 | 54 | 62 | 85 | 4.2 |
| 444660 | 42 | 48 | 64 | 9.5 |
| 444661 | 49 | 57 | 74 | 5.9 |
| 444663 | 42 | 65 | 84 | 5.1 |

The ten compounds marked with an asterisk had an improved ED50 over ISIS 388241.

## Example 5

### Assay for Neurotoxic Effects of Bolus Administration of Antisense Oligonucleotides in the Striatal Tissue of Rats

About 30 compounds were selected as having high tolerability and high potency. Compounds were then tested by CNS bolus injection in rat to further assess neurotoxicity.

Sprague-Dawley rats each were treated with ISIS oligonucleotides via bolus administration to a defined brain area, the striatum, for the purpose of screening for the induction of the microglial marker AIF1 as a measure of CNS toxicity.

Treatment and Surgery

Groups of four Sprague-Dawley rats were administered with ISIS 387916, ISIS 388241, ISIS 419627, ISIS 419628, ISIS 419629, ISIS 419630, ISIS 419636, ISIS 419637, ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436668, ISIS 4196671, ISIS 436684, ISIS 436689, ISIS 436754, ISIS 443168, ISIS 437175, ISIS 437441, ISIS 437442, ISIS 437507, ISIS 437527, ISIS 443139, ISIS 444578, ISIS 444584, ISIS 444591, ISIS 444607, ISIS 444608, ISIS 444615, ISIS 444618, ISIS 444627, ISIS 444652, ISIS 444658, ISIS 444659, ISIS 444660, ISIS 444661, or ISIS 444663 delivered as a single bolus injection at 50 μg concentration into the striatum.



A control group of 4 rats were similarly treated with PBS. A group of 4 rats were similarly treated with ISIS 104838, an antisense oligonucleotide against TNF-α, as a negative control group. ISIS 387916 was administered in four groups of 4 rats each and the results presented are an average of the data derived from the 16 rats. ISIS 419628 was administered in two groups of 4 rats each and the results presented are the average of the data from the 8 rats. ISIS 419629, ISIS 444584 and ISIS 444618, which had toxic indicators in the systemic administration study (Example 3) were also tested in this study. Seven days after bolus administration, the rats were euthanized using isoflurane and the organs were removed. The animals were decapitated and the brain was removed for dissection of the striatal tissue.

RNA Analysis of AIF1 Expression Levels

RNA was extracted from striatal tissue for real-time PCR analysis of AIF1 mRNA levels. Rat AIF1 levels were measured using the rat primer probe set rAif1_LTS00219 (forward sequence AGGAGAAAAACAAAGAACACCAGAA, designated herein as SEQ ID NO: 46; reverse sequence CAATTAGGGCAACTCAGAAATAGCT, designated herein as SEQ ID NO: 47; probe sequence CCAACTGGTCCCCCAGCCAAGAX, designated herein as SEQ ID NO: 48). Results were calculated as the percentage of AIF1 expression over that of the PBS control and are presented in Table 53. ISIS 419629, ISIS 444584, and ISIS 444618, which had toxic indicators in the systemic administration study (in Example 3), also had toxic indicators in this study (greater than 300% above saline control). Later studies showed that ISIS 444584 is neurotolerable and exhibits negligible toxic indicators (see Example 16 and 17).

TABLE 53

| Percent expression of AIF1 mRNA levels in vivo as a measure of neurotoxicity | |
|---|---|
| ISIS No. | % expression |
| 104838 | 111 |
| 387916 | 870 |
| 388241 | 236 |
| 419627 | 168 |
| 419628 | 497 |
| 419629 | 247 |
| 419630 | 227 |
| 419636 | 464 |
| 419637 | 275 |
| 419640 | 305 |
| 419641 | 206 |
| 419642 | 173 |
| 436665 | 217 |
| 436668 | 447 |
| 436671 | 239 |
| 436684 | 700 |
| 436689 | 149 |
| 436754 | 125 |
| 437168 | 130 |
| 437175 | 131 |
| 437441 | 158 |
| 437442 | 157 |
| 437507 | 133 |
| 437527 | 184 |
| 443139 | 143 |
| 444578 | 352 |
| 444584 | 317 |
| 444591 | 194 |
| 444607 | 362 |
| 444608 | 476 |
| 444615 | 645 |
| 444618 | 547 |
| 444627 | 377 |
| 444652 | 336 |
| 444658 | 364 |

TABLE 53-continued

| Percent expression of AIF1 mRNA levels in vivo as a measure of neurotoxicity | |
|---|---|
| ISIS No. | % expression |
| 444659 | 319 |
| 444660 | 411 |
| 444661 | 249 |
| 444663 | 448 |

RNA Analysis of Huntingtin Expression Levels

RNA was extracted from striatal tissue for real-time PCR analysis of huntingtin mRNA levels. Rat huntingtin mRNA levels were measured using the rat primer probe set rHtt_LTS00343 (forward sequence CAGAGCTGGTGAACCG-TATCC, designated herein as SEQ ID NO: 49; reverse sequence GGCTTAAGCAGGGAGCCAAAA, designated herein as SEQ ID NO: 50; probe sequence ACTTCATGAT-GAGCTCGGAGTTCAACX, designated herein as SEQ ID NO: 51). Results were calculated as the percentage reduction of huntingtin expression over that of the PBS control and are presented in Table 54. ISIS 388241, ISIS 436684, ISIS 436754, ISIS 437175, ISIS 437507, and ISIS 443139 are each mismatched by 6 base pairs or more with the rat gene sequence (SEQ ID NO: 5) and therefore do not show significant inhibition of rat mRNA levels compared to the control. ISIS 419640, ISIS 419641, ISIS 419642, ISIS 436665, ISIS 436668, ISIS 437442, ISIS 444615, and ISIS 444627 have 1 mismatch each with the rat gene sequence (SEQ ID NO: 5) and do not show significant inhibition of rat mRNA levels compared to the control. ISIS 437168 and ISIS 437441 have 2 mismatches each with the rat gene sequence (SEQ ID NO: 5) and do not show significant inhibition of rat mRNA levels compared to the control. ISIS 436689 and ISIS 444584 have 3 mismatches each with the rat gene sequence (SEQ ID NO: 5) and do not show significant inhibition of rat mRNA levels compared to the control.

TABLE 54

| Percent reduction of rat huntingtin mRNA levels in rats | |
|---|---|
| ISIS No. | % reduction |
| 387916 | 70 |
| 419627 | 67 |
| 419628 | 57 |
| 419629 | 85 |
| 419630 | 11 |
| 419636 | 53 |
| 419637 | 84 |
| 436671 | 77 |
| 437527 | 86 |
| 444578 | 72 |
| 444591 | 35 |
| 444607 | 57 |
| 444608 | 68 |
| 444618 | 56 |
| 444652 | 75 |
| 444658 | 61 |
| 444659 | 55 |
| 444660 | 63 |
| 444661 | 52 |
| 444663 | 59 |

Example 6

Intracerebroventricular Administration of Antisense Oligonucleotides Against Huntingtin mRNA-Tolerability Study in BACHD Mice

Selected compounds were compared with previously designed compound ISIS 388241 by ICV administration in BACHD mice.

Selected compounds plus the benchmark 388241 were selected based on in vitro and systemic potency and systemic tolerability as well as CNS potency and tolerability.

BACHD mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration to a defined mouse brain area, the right lateral ventricle, for the purpose of evaluating the tolerability of ICV dosing in mice.

Treatment and Surgery

Groups of five BACHD mice each were administered ISIS 388241, ISIS 437507, ISIS 443139, ISIS 419640, ISIS 419641, ISIS 419642, ISIS 444591, ISIS 436665, ISIS 436671, ISIS 444661, or ISIS 436689 at 150 μg/day delivered ICV with Alzet 2002 pumps at the rate of 12 μL/day for 2 weeks. A control group of 4 BACHD mice were similarly treated with PBS. The mice were surgically implanted with the pumps in the following manner: Mice were individually anaesthetized with 3% isoflurane for pump implantation. After two weeks, the mice were anesthetized again and the pump was surgically removed. The animals were then allowed to recover for two more weeks before being euthanized.

The body weights of the mice were taken weekly during the treatment and recovery periods. After 4 weeks, the mice were euthanized using isoflurane and decapitated. The brain was removed for tissue acquisition from the anterior and posterior sections.

RNA Analysis

RNA was extracted from the right hemisphere of the anterior cortex and the posterior cerebellar section of the cannulation site for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin mRNA levels were measured using the murine primer probe set RTS2633. Results were calculated as percent inhibition of human and murine huntingtin mRNA expression compared to the control and are presented in Tables 56 and 57 respectively. All the antisense oligonucleotides effect significant inhibition of human huntingtin mRNA levels. ISIS 388241, ISIS 437507, and ISIS 443139 are each mismatched by 8 base pairs or more with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore do not show significant inhibition of murine mRNA levels compared to the control. ISIS 444591 has 1 mismatch with the murine huntingtin mRNA (SEQ ID NO: 3) and does not show significant inhibition of murine mRNA levels compared to the control. ISIS 436689 has 3 mismatches with the murine huntingtin mRNA (SEQ ID NO: 3) and does not show significant inhibition of murine mRNA levels compared to the control.

TABLE 56

| Percent reduction of human huntingtin mRNA levels in BACHD mice via ICV administration of antisense oligonucleotides | | | |
|---|---|---|---|
| ISIS No. | Number of mice | Anterior cortex | Posterior cortex |
| 388241 | 3 | 82 | 70 |
| 419640 | 1 | 60 | 46 |

TABLE 56-continued

| Percent reduction of human huntingtin mRNA levels in BACHD mice via ICV administration of antisense oligonucleotides | | | |
|---|---|---|---|
| ISIS No. | Number of mice | Anterior cortex | Posterior cortex |
| 419641 | 2 | 75 | 66 |
| 419642 | 3 | 29 | 42 |
| 436665 | 5 | 62 | 38 |
| 436671 | 3 | 69 | 77 |
| 436689 | 3 | 49 | 40 |
| 437507 | 3 | 77 | 66 |
| 443139 | 5 | 93 | 90 |
| 444591 | 5 | 79 | 78 |

TABLE 57

| Percent reduction of murine huntingtin mRNA levels in BACHD mice via ICV administration of antisense oligonucleotides | | | |
|---|---|---|---|
| ISIS No. | Number of mice | Anterior cortex | Posterior cortex |
| 419640 | 1 | 22 | 34 |
| 419641 | 2 | 40 | 26 |
| 419642 | 3 | 63 | 71 |
| 436665 | 5 | 72 | 56 |
| 436671 | 3 | 80 | 71 |

Body Weight Measurement

The body weights of the mice were measured at the onset of the study and subsequently once a week. The body weights of the mice are presented in Table 58 and are expressed as a percent change over the weights taken at the start of the study. The body weights were considered a measure of the tolerability of the mice to the ICV administration of antisense oligonucleotide. 'n.d.' means that there was no data available for that time period.

TABLE 58

| Percent change in body weight of BACHD mice during antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| | week 1 | week 2 | week 3 | week 4 |
| PBS | −1 | +2 | +6 | +6 |
| ISIS 388241 | +3 | +11 | +15 | +7 |
| ISIS 437507 | +21 | +10 | +13 | −4 |
| ISIS 443139 | +10 | +10 | +16 | +12 |
| ISIS 419640 | +21 | +11 | −10 | +9 |
| ISIS 419641 | +24 | +3 | −5 | −12 |
| ISIS 419642 | +45 | +39 | +12 | +1 |
| ISIS 444591 | +18 | +38 | +27 | +17 |
| ISIS 436665 | +34 | +43 | +23 | +9 |
| ISIS 436671 | +19 | +17 | +11 | 0 |
| ISIS 444661 | +19 | −10 | −21 | n.d. |
| ISIS 436689 | +49 | +40 | +2 | −17 |

Survival of the Mice

The survival of the mice was assessed throughout the entire study period. Table 59 below shows the survival pattern in the groups of mice treated with ISIS oligonucleotides as well as the control.

TABLE 59

| Number of survivals during antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| | week 1 | week 2 | week 3 | week 4 |
| PBS | 5 | 5 | 5 | 5 |
| ISIS 388241 | 4 | 3 | 3 | 3 |
| ISIS 437507 | 5 | 5 | 4 | 4 |
| ISIS 443139 | 5 | 5 | 5 | 5 |
| ISIS 419640 | 5 | 5 | 4 | 1 |
| ISIS 419641 | 5 | 5 | 4 | 2 |
| ISIS 419642 | 5 | 5 | 4 | 2 |
| ISIS 444591 | 5 | 5 | 5 | 5 |
| ISIS 436665 | 5 | 5 | 5 | 5 |
| ISIS 436671 | 4 | 4 | 3 | 3 |
| ISIS 444661 | 5 | 5 | 1 | 0 |
| ISIS 436689 | 4 | 4 | 4 | 3 |

## Example 7

### Intracerebroventricular Administration of Antisense Oligonucleotides Against Huntingtin in C57/BL6 Mice

Wild-type C57/BL6 mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration to a defined mouse brain area, the right lateral ventricle, for the purpose of evaluating the potency of the oligonucleotides against mouse huntingtin in these mice.

Treatment and Surgery

Groups of ten C57/BL6 mice each were administered ISIS 408737 (5' TCCTAGTGTTACATTACCGC 3' (SEQ ID NO: 52), start site 5263 of SEQ ID NO: 3) at 50 μg/day delivered ICV with Alzet 2002 pumps at the rate of 0.5 μL/day for 7 days or 14 days. A control group of six C57/BL6 mice were similarly treated with PBS. The mice were surgically implanted with the pumps in the following manner: Briefly, Alzet osmotic pumps (Model 2002) were assembled according to manufacturer's instructions. Pumps were filled with a solution containing the antisense oligonucleotide and incubated overnight at 37° C., 24 hours prior to implantation. Animals were anesthetized with 3% isofluorane and placed in a stereotactic frame. After sterilizing the surgical site, a midline incision was made over the skull, and a subcutaneous pocket was created over the back, in which a pre-filled osmotic pump was implanted. A small burr hole was made through the skull above the right lateral ventricle. A cannula, connected to the osmotic pump via a plastic catheter, was then placed in the ventricle and glued in place using Loctite adhesive. The incision was closed with sutures. Antisense oligonucleotide or PBS was infused for 7 or 14 days, after which animals were euthanized according to a humane protocol approved by the Institutional Animal Care and Use Committee. Brain and spinal cord tissue were harvested and snap frozen in liquid nitrogen. Prior to freezing, brain tissue was cut transversely into five sections (51, S2, S3, S4, and S5) using a mouse brain matrix. Sections 1 to 5 were approximately 2 mm apart from each other with S1 being most rostral and S5 most caudal.

RNA and Protein Analysis

Total RNA was extracted from mouse brain and spinal cord with RNeasy Protect Mini Kit (Qiagen, Mississauga, ON, Canada) for real-time PCR analysis of huntingtin mRNA levels using an RNeasy Mini prep kit (Qiagen). Q-PCR reactions were conducted and analyzed on an ABI Prism 7700 Sequence Detector (Applied Biosystems). Mouse huntingtin mRNA levels were measured using the murine primer probe set ABI #Mm01213820_m1 (Applied Biosystems) and normalized to peptidylprolyl isomerase A mRNA levels. Protein lysates were prepared from mouse brain slabs as described previously (Li S. H. and Li X. J., *Methods in Molecular Biology* (2008), 217:1940-6029). Lysates were run on 3-8% tris-acetate gel and transferred using the iBlot dry blotting system (Invitrogen). Blots were probed with anti-beta tubulin (Chemicon) and monoclonal MAB2166 antibody (Millipore) that reacts specifically with murine huntingtin protein. Immunoblots were quantified using Odyssey V 3.0 software.

The results are presented in Table 60 as percent reduction compared to the PBS control and demonstrate significant inhibition of huntingtin mRNA and protein levels by the antisense oligonucleotide both at day 7 and day 14.

TABLE 60

Percent inhibition of murine huntingtin mRNA in C57/BL6 mice

| | day 7 | day 14 |
|---|---|---|
| mRNA | 66 | 68 |
| protein | 21 | 49 |

## Example 8

### Intracerebroventricular Administration of Antisense Oligonucleotides Against Huntingtin mRNA in Cynomologous Monkeys

Cynomologous monkeys were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration to a defined brain area, the lateral ventricles, for the purpose of screening the activity of the oligonucleotides in brain tissue against huntingtin mRNA expression.

Treatment and Surgery

Two groups of 3 cynomologous monkeys each were administered either 0.635 mg/ml (1.5 mg/day) or 1.67 mg/ml (4 mg/day) of ISIS 436689 delivered ICV with individual ambulatory pumps (Pegasus Vario) at the rate of 0.05 ml/hr for 4 weeks. A control group of 2 cynomologous monkeys were administered with PBS in a similar manner. The groups were administered ISIS 436689 bilaterally. One animal was administered ISIS 436689 at the 4 mg/day dose unilaterally to the right ventricle.

Animals were allowed 10 days to recover from surgery prior to infusion being performed. During the post surgery recovery period, the animals were maintained on PBS ICV infusion at a flow rate of 0.05 mL/h using one ambulatory infusion pump per ventricle. At the end of the recovery period, each cannula was connected to an individual ambulatory pump (Pegasus Vario) placed within a primate jacket (Lomir, PJ-02NB). The pumps remained connected until completion of the infusion period. After 4 weeks administration, the animals were euthanized and the brain, liver and kidney were harvested.

RNA analysis of htt mRNA

RNA was extracted from the anterior caudate, posterior caudate, temporal cortex, parietal cortex, hypothalamus, midbrain, hippocampus, and spinal cords, as well as the liver and kidney for real-time PCR analysis of huntingtin mRNA levels. Huntingtin mRNA levels were measured using the human primer probe set RTS2617 and normalized to monkey cyclophilin A levels. Results were calculated as percent inhibition of huntingtin mRNA expression compared to the PBS control and are presented in Table 61. ISIS 436689 effected significant inhibition of human huntingtin mRNA levels in the CNS.



TABLE 61

Percent reduction of huntingtin mRNA levels in cynomologous monkeys via ICV administration of antisense oligonucleotides

| | Dose (mg/day) | | | |
|---|---|---|---|---|
| Tissue | 1.5 (bilateral) | 4 (bilateral) | 4 (right unilateral) | 4 (left unilateral) |
| Anterior caudate | 59 | 49 | 85 | 12 |
| Posterior caudate | 52 | 81 | 63 | 0 |
| Temporal cortex | 10 | 34 | 41 | 31 |
| Parietal cortex | 22 | 38 | 46 | 24 |
| Hypothalamus | 59 | 71 | 35 | 100 |
| Mid-brain | 32 | 38 | 2 | 0 |
| Hippocampus | 18 | 18 | 28 | 10 |
| Cervical cord | 58 | 65 | n.d. | n.d. |
| Thoracic cord | 50 | 67 | n.d. | n.d. |
| Lumbar cord | 49 | 62 | n.d. | n.d. |
| Liver | 0 | 13 | n.d. | n.d. |
| Kidney | 0 | 13 | n.d. | n.d. |

n.d. = no data

## Example 9

### Measurement of Half-Life of ISIS 387898 in the Striatum of C57/BL6 Mice Via Single Bolus Administration

C57/BL6 mice were administered ISIS 387898 as a single bolus to the striatum for the purpose of measuring half-life and duration of action of the antisense oligonucleotide against huntingtin mRNA expression in that tissue.

Treatment

Forty C57/BL6 mice were treated with ISIS 387898 (5' CTCGACTAAAGCAGGATTTC 3' (SEQ ID NO: 53); start position 4042 of SEQ ID NO: 1 and start position 4001 of SEQ ID NO: 3) delivered as a single bolus of 50 μg in a procedure similar to that described in Example 5. Eight control C57/BL6 mice were treated with PBS in a similar procedure. Groups of 4 mice each were euthanized at various time points and striatal tissue extracted in a procedure similar to that described in Example 5.

RNA Analysis

RNA was extracted from striatal tissue for real-time PCR analysis of huntingtin mRNA levels. Mouse normal huntingtin mRNA levels were measured using the murine primer probe set RTS2633. The results are presented in Table 62 and are expressed as percent inhibition compared to the PBS control group at day 7. The inhibitory effect of ISIS 387898 was observed to be prolonged for at least 91 days.

TABLE 62

Effect of ISIS 387898 as a single bolus administration on murine huntingtin mRNA expression at various time points in C57/BL6 striatum

| Treatment | Days after dosing | % inhibition |
|---|---|---|
| ISIS 387898 | 1 | 66 |
| | 7 | 74 |
| | 14 | 68 |
| | 21 | 77 |
| | 28 | 75 |
| | 50 | 63 |
| | 73 | 55 |
| | 91 | 48 |
| PBS | 50 | 5 |

Analysis of Antisense Oligonucleotide Concentration in the Brain:

Brain tissues were minced, weighed, homogenized, and extracted using a phenol/chloroform liquid-liquid extraction method. This was followed by solid phase extraction of the supernatant on a phenyl-bonded column before capillary gel eletrophoresis electrokinetic injection. A P/ACE MDQ capillary electrophoresis instrument (Beckman Coulter, Fullerton, Calif.) was used for gel-filled capillary electrophoretic analysis. Oligonucleotide peaks were detected by UV absorbance at 260 nm.

The concentration of ISIS 387898 in the brain (μg/g) was plotted against the expression of human huntingtin as a percentage of the PBS control (Table 63 and FIG. **1**). The concentration of ISIS 387898 which achieves 50% inhibition of huntingtin mRNA expression ($EC_{50}$) was calculated. The $EC_{50}$ was determined to be 0.45 μg/g. The time-dependent concentration of ISIS 387898 in the brain tissue and corresponding percentage huntingtin mRNA expression was also plotted (Table 64 and FIG. **2**) and the half-life of the oligonucleotide was calculated as 21 days.

TABLE 63

Concentration of ISIS 387898 in brain tissue and its effect on htt mRNA expression as a percentage of the control

| concentration (μg/g) | % mRNA expression |
|---|---|
| 0 | 105.0 |
| 25 | 28.8 |
| 50 | 28.2 |
| 75 | 27.9 |
| 100 | 27.8 |
| 125 | 27.8 |

TABLE 64

Time-dependent concentration of ISIS 387898 in brain tissue and its effect on htt mRNA expression as a percentage of the control

| Time (day) | Conc (μg/g) | mRNA % expression |
|---|---|---|
| 1 | 116 | 35 |
| 7 | 65.7 | 27 |
| 14 | 30 | 32 |
| 23 | 34.9 | 24 |
| 30 | 12.2 | 26 |
| 51 | 2.1 | 38 |
| 73 | 1.4 | 47 |
| 92 | 1.1 | 53 |

## Example 10

### Measurement of Half-Life of ISIS 387898 in the Lateral Ventricles of BACHD Mice Via ICV Administration

BACHD mice were administered ISIS 387898 by ICV to the lateral ventricles of the brain for the purpose of measuring half-life and duration of action of the antisense oligonucleotide against huntingtin mRNA expression in that tissue.

Treatment

Twenty eight BACHD mice were treated with ISIS 387898 delivered by ICV administration at 75 μg/day for 2 weeks in a procedure similar to that described in Example 9. Twenty eight control BACHD mice were treated with PBS in a procedure similar to that described in Example 9. Groups of 4 mice each from both the treatment and control groups were euthanized at biweekly time points and anterior cortical tissue extracted in a procedure similar to that described in Example 9.

RNA Analysis

RNA was extracted from the right hemisphere, both anterior and posterior to the cannulation site for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. Mouse normal huntingtin mRNA levels were measured using the murine primer probe set RTS2633. Human mutant huntingtin mRNA expression levels are presented in Table 65 and are expressed as percent inhibition compared to the average of that measured in the PBS control groups. Murine normal huntingtin mRNA expression levels are presented in Table 66 and are expressed as percent inhibition compared to the average of that measured in the PBS control groups. The inhibitory effect of ISIS 387898 was observed to be prolonged for 91 days.

TABLE 65

Effect of ISIS 387898 administered ICV on human huntingtin mRNA expression at various time points

| Treatment | Days after dosage | anterior | posterior |
|---|---|---|---|
| ISIS 387898 | 14 | 74 | 65 |
| | 28 | 67 | 61 |
| | 42 | 70 | 61 |
| | 56 | 57 | 52 |
| | 70 | 57 | 43 |
| | 91 | 41 | 61 |
| | 127 | 28 | 16 |
| PBS | 14 | 0 | 0 |
| | 28 | 0 | 0 |
| | 42 | 1 | 0 |
| | 56 | 9 | 10 |
| | 70 | 13 | 10 |
| | 91 | 13 | 25 |
| | 127 | 11 | 0 |

TABLE 66

Effect of ISIS 387898 administered ICV on murine huntingtin mRNA expression at various time points

| Treatment | Days after dosage | anterior | posterior |
|---|---|---|---|
| ISIS 387898 | 14 | 85 | 81 |
| | 28 | 81 | 69 |
| | 42 | 86 | 79 |
| | 56 | 74 | 69 |
| | 70 | 73 | 58 |
| | 91 | 39 | 63 |
| | 127 | 39 | 0 |
| PBS | 14 | 0 | 0 |
| | 28 | 0 | 0 |
| | 42 | 0 | 0 |
| | 56 | 17 | 14 |
| | 70 | 5 | 24 |
| | 91 | 9 | 17 |
| | 127 | 32 | 0 |

Analysis of Antisense Oligonucleotide Concentration in the Brain:

Brain tissue was processed in a procedure similar to that described in Example 9. The concentration of ISIS 387898 in the anterior cortex of the brain (μg/g) was plotted against the inhibition of human huntingtin as a percentage of the PBS control (Table 67 and FIG. **3**), and the $EC_{50}$ was calculated to be 26.4 μg/g. The time-dependent concentration of ISIS 387898 in the brain tissue was also plotted (Table 68 and FIG. **4**) and the half-life of the oligonucleotide was calculated as 21 days.

TABLE 67

Concentration of ISIS 387898 in brain tissue and its effect on htt mRNA expression as a percentage of the control

| Concentration (μg/g) | % mRNA expression |
|---|---|
| 0 | 105 |
| 10 | 90.7 |
| 100 | 19.3 |
| 200 | 14.3 |
| 300 | 13.2 |
| 400 | 12.7 |
| 500 | 12.5 |
| 600 | 12.4 |

TABLE 68

Time-dependent concentration of ISIS 387898 in brain tissue and its effect on htt mRNA expression as a percentage of the control

| Days after last dose | Conc (mg/g) | % mRNA expression |
|---|---|---|
| 14 | 554.3 | 12 |
| 28 | 219.8 | 15 |
| 42 | 154 | 13 |
| 56 | 146.9 | 32 |
| 70 | 48.3 | 28 |
| 91 | 46.1 | 66 |
| 127 | 11.8 | 90 |

## Example 11

### Measurement of Half-Life of ISIS 388241 and ISIS 443139 in the Lateral Ventricles of BACHD Mice Via ICV Administration

BACHD mice were administered ISIS 388241 or ISIS 443139 by ICV to the lateral ventricles of the brain for the purpose of measuring half-life and duration of action of the antisense oligonucleotide against huntingtin mRNA expression in that tissue.

Treatment

Twenty BACHD mice were treated with ISIS 38241 delivered by ICV administration at 50 μg/day for 2 weeks in a procedure similar to that described in Example 9. Twenty BACHD mice were treated with ISIS 443139 delivered by ICV administration at 50 μg/day for 2 weeks in a procedure similar to that described in Example 9. Twenty control BACHD mice were treated with PBS in a procedure similar to that described in Example 9. Groups of 4 mice each from both the treatment groups and control group were euthanized at biweekly time points and tissue extracted in a procedure similar to that described in Example 9.

RNA Analysis

RNA was extracted from the right hemisphere, both anterior and posterior to the cannulation site for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using the human primer probe set RTS2617. The results are presented in Table 69 and are expressed as percent inhibition compared to the average of that measured in the PBS control groups. The inhibitory effects of both ISIS 388241 and ISIS 443139 were observed to be prolonged for at least 16 weeks.

Both ISIS 388241 and its mixed backbone equivalent, ISIS 443139, have more than 3 mismatches with murine huntingtin mRNA (SEQ ID NO: 5) and therefore did not show significant inhibition of murine mRNA levels compared to the control.

TABLE 69

Effect of ISIS 388241and ISIS 443139 administered ICV on human huntingtin mRNA expression at various time points

| Treatment | Weeks after dosage | anterior | posterior |
|---|---|---|---|
| ISIS 388241 | 0 | 63 | 64 |
| | 4 | 79 | 56 |
| | 8 | 67 | 51 |
| | 12 | 76 | 68 |
| | 16 | 35 | 34 |
| ISIS 443139 | 0 | 35 | 55 |
| | 4 | 20 | 62 |
| | 8 | 61 | 59 |
| | 12 | 67 | 53 |
| | 16 | 46 | 37 |
| PBS | 0 | 15 | 10 |
| | 4 | 0 | 2 |
| | 8 | 5 | 0 |
| | 12 | 32 | 4 |
| | 16 | 6 | 2 |

Analysis of Antisense Oligonucleotide Concentration in the Brain:

Brain tissue was processed in a procedure similar to that described in Example 9. The time-dependent concentration of ISIS 388241 in the posterior brain tissue was plotted (Table 70 and FIG. **5**) and the half-life of the oligonucleotide was calculated as 20 days. The time-dependent concentration of ISIS 443139 in the posterior brain tissue was plotted (Table 71 and FIG. **6**) and the half-life of the oligonucleotide was calculated as 20 days.

TABLE 70

Concentration of ISIS 384241 in brain tissue and its effect on htt mRNA expression as a percentage of the control

| Days after last dose | Conc (ug/g) | % mRNA expression |
|---|---|---|
| 0 | 170.3 | 36 |
| 28 | 65.2 | 43 |
| 56 | 13 | 49 |
| 84 | 8.2 | 32 |
| 112 | 6.9 | 66 |

TABLE 71

| Concentration of ISIS 443139 in brain tissue and its effect on htt mRNA expression as a percentage of the control | | |
|---|---|---|
| Days after last dose | Conc (ug/g) | % mRNA expression |
| 0 | 71.3 | 45 |
| 28 | 47.4 | 38 |
| 56 | 11.3 | 41 |
| 84 | 11.1 | 46 |
| 112 | 5.6 | 63 |

## Example 12

### Effect of Antisense Inhibition of Mutant Human Huntingtin on the Motor Performance of BACHD Mice

BACHD mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration for the purpose of evaluating the effect of the oligonucleotides against huntingtin mRNA expression on their motor performance via the rotarod assay.

Treatment

The accelerating rotarod assay was performed on the Ugo Basile rotarod. Animals were placed on the rotarod at a speed of 2 RPM, the rotarod accelerated to 40 RPM over 5 minutes. The duration to fall was recorded. Duration to fall is defined by the animal either falling from the rotarod, or stopping their run, hanging on to the rotarod and rotating on it. Six month old BACHD mice and their non-transgenic littermates were trained to run on the rotarod for one week prior to treatment. This consisted of three consecutive trials of 5 minutes each, with a 20 minute rest period between trials. A group of 15 BACHD mice were then treated with ISIS 388241 at 50 μg/day delivered ICV with Alzet 2002 pumps at the rate of 12 μL/day for 2 weeks. The mice were surgically implanted with the pumps in a similar procedure as that described in Example 6. A control group of 14 BACHD mice were treated with PBS in a similar manner. A control group of 9 non-transgenic littermates were treated with PBS in a similar manner.

Rotarod Performance Assay

At the end of the treatment period, the pumps were removed and two weeks later, the first post-treatment rotarod assay was conducted. Rotarod behavior was analyzed monthly till the mice were 11 months of age. Each month, the animals were placed on the rotarod for three trial runs a day for 2 days. The results are presented in FIG. **7**, as well as in Table 72 expressed as duration to fall in seconds. Baseline values at 6 months age were taken before the treatment and the time points given are the age of the mice at which the assay was conducted. The data indicates that treatment of BACHD mice with ISIS 388241 increased the duration to fall compared to that observed in untreated BACHD mice.

TABLE 72

| Effect of antisense inhibition of mutant huntingtin mRNA on duration to fall (sec) | | | | | | |
|---|---|---|---|---|---|---|
| | 6 months | 7 month | 8 months | 9 months | 10 months | 11 months |
| ISIS 388241 | 97 | 108 | 154 | 148 | 144 | 159 |
| PBS control | 94 | 117 | 115 | 104 | 99 | 92 |
| Non-transgenic control | 197 | 198 | 215 | 207 | 198 | 199 |

## Example 13

### Effect of Antisense Inhibition of Mutant Human Huntingtin and Wild Type Murine Huntingtin mRNA on the Motor Performance of BACHD Mice

BACHD mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration for the purpose of evaluating the effect of the oligonucleotides against huntingtin mRNA expression on their motor performance via the rotarod assay.

Treatment

The accelerating rotarod assay was performed on the Ugo Basile rotarod. Animals were placed on the rotarod at a speed of 2 RPM, the rotarod accelerated to 40 RPM over 5 minutes. The duration to fall was recorded. Duration to fall is defined by the animal either falling from the rotarod, or stopping their run, hanging on to the rotarod and rotating on it. Two month old BACHD mice and their non-transgenic littermates were trained to run on the rotarod for one week prior to treatment. This consisted of three consecutive trials of 5 minutes each, with a 20 minute rest period between trials. Groups of 17-21 BACHD mice each were then treated with ISIS 388241 at 50 μg/day, ISIS 408737 at 75 μg/day, or ISIS 387898 at 75 μg/day, delivered ICV with Alzet 2002 pumps at the rate of 0.5 μL/hour for 2 weeks. The mice were surgically implanted with the pumps in a similar procedure as that described in Example 6. A control group of 20 BACHD mice were treated with PBS in a similar manner. Groups of non-transgenic control mice were also similarly treated with ISIS oligonucleotides or PBS in a similar manner.

Rotarod Performance Assay

At the end of the treatment period, the pumps were removed and two weeks later, the first post-treatment rotarod assay was conducted. Rotarod behavior was analyzed monthly till the mice were 10 months of age. Each month, the animals were placed on the rotarod for 3-5 trial runs a day for 3 consecutive days. The results are presented in Table 73 expressed as duration to fall in seconds. Baseline values at 2 months age were taken before the treatment and the time points given are the age of the mice at which the assay was conducted. ISIS 387898 (designated in the table as Human-mouse ASO) is cross-reactive for both mouse and human huntingtin mRNA and therefore would inhibit both human mutant huntingtin mRNA and wild-type murine huntingtin mRNA in the mice. ISIS 388241 (designated in the table as Human ASO) specifically targets human huntingtin mRNA and is mismatched by 8 base pairs with murine huntingtin mRNA. Therefore, ISIS 388241 would specifically inhibit only human mutant huntingtin mRNA and not wild-type murine huntingtin mRNA in the mice. ISIS 408737 (designated in the table as Mouse ASO) specifically targets murine huntingtin mRNA and is mismatched by 7 base pairs with human huntingtin mRNA. Therefore, ISIS 408737 would specifically inhibit only wild-type murine huntingtin mRNA and not human mutant huntingtin mRNA in the mice. 'Tg' indicates the BACHD mice and 'Non-Tg' indicates the non-transgenic control mice.

The results of the study indicate that inhibition of human mutant huntingtin mRNA by ISIS 388241 (Tg-Human ASO) significantly improved the performance of the mice in the rotarod assay compared to the control (Tg-PBS). The results also indicate that treatment of mice with ISIS 387898 (Tg-Human-mouse ASO), which targets both mutant and wild-type huntingtin mRNA in the mice, did not cause any deleterious effects on the motor performance of the mice and, in fact, also significantly improved rotarod performance compared to the control (Tg-PBS). The mice treated with ISIS 408737 (Tg-Mouse ASO) did not show improved rotarod performance compared to the PBS control, as expected, since the oligonucleotide does not target the mutant huntingtin mRNA. The non-transgenic controls were utilized as positive controls in this assay.

TABLE 73

| Effect of antisense inhibition of huntingtin mRNA on duration to fall (sec) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 months | 3 months | 4 months | 5 months | 6 months | 7 months | 8 months | 9 months | 10 months |
| Tg-Human ASO | 146 | 167 | 190 | 192 | 190 | 188 | 181 | 191 | 191 |
| Tg-mouse ASO | 151 | 142 | 152 | 143 | 139 | 144 | 139 | 123 | 130 |
| Tg-Human-mouse ASO | 149 | 187 | 203 | 199 | 196 | 194 | 189 | 194 | 171 |
| Tg-PBS | 152 | 164 | 169 | 160 | 159 | 155 | 148 | 135 | 136 |
| Non-Tg-Human ASO | 212 | 223 | 234 | 236 | 247 | 248 | 245 | 247 | 235 |
| Non-Tg-Mouse ASO | 201 | 212 | 215 | 213 | 231 | 243 | 244 | 250 | 247 |
| Non-Tg-Human-mouse ASO | 220 | 240 | 239 | 224 | 243 | 244 | 246 | 229 | 235 |
| Non-Tg-PBS | 193 | 220 | 228 | 227 | 228 | 216 | 220 | 208 | 208 |

## Example 14

### Effect of Antisense Inhibition of Huntingtin mRNA on the Brain Mass of R6/2 Mice

R6/2 mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration for the purpose of evaluating the effect of the oligonucleotides against huntingtin mRNA expression on brain weight and volume.

Treatment

R6/2 mice were housed in groups of up to 5 per cage (mixed genotypes, single sex), All mice were housed in shoe-box cages with sterile wood bedding covering the ground that were changed as frequently as needed to provide the animals with dry bedding. This basic environment was enriched with the addition of play tunnels, shredded nestlet, and plastic bones for all mice; i.e. an environmentally-enriched cage containing a Mouse Tunnel, (amber color, certified, transparent, BioSery Product# K3323), a Petite Green Gumabone (BioSery Product # K3214) and a nestlet (Hockley et al., Ann Neurol. 2002, 51: 235-242). Food and water were available ad libitum to the mice in their home cages.

A group of ten six month old R6/2 mice was administered 50 μg/day of ISIS 388817 delivered ICV with Alzet 1004 pumps at the rate of 0.12 μl/hr for 4 weeks. A group of two non-transgenic littermates was administered 50 μg/day of ISIS 388817 delivered in a similar manner. A control group of five R6/2 mice was administered 50 μg/day of ISIS 141923 delivered in a similar manner. A control group of nine R6/2 mice was administered PBS delivered in a similar manner. A group of eight non-transgenic littermates was administered PBS delivered in a similar manner. A group of four untreated eight-week old pre-symptomatic R6/2 were also included in the study.

Brain Weight Measurement

Animals were anaesthetized with isofluorane and then subjected to transcardial perfusion with ice-cold Sorenson's phosphate buffer (SPB), and fixed with 4% paraformaldyhyde in SPB.

Brains were removed, and trimmed with coronal cuts immediately rostral to the forebrain (removing the olfactory bulbs) and immediately caudal to the cerebellum (removing the spinal cord). The remaining brain was weighed in mg. The results are presented in FIG. **8** and Table 74 and demonstrate the increase in brain weight in R6/2 mice treated with ISIS 388817 compared to the PBS control

TABLE 74

| Effect of antisense inhibition of mutant huntingtin mRNA on brain weight (mg) | | |
|---|---|---|
| Mouse model | Treatment | Brain weight |
| R6/2 | PBS | 367 |
| | ISIS 141923 | 375 |
| | ISIS 388817 | 394 |
| R6/2 (8 weeks old) | None | 402 |
| Non-transgenic | ISIS 141923 | 452 |
| | ISIS 388817 | 436 |

## Example 15

### Effect of Antisense Inhibition of Huntingtin mRNA on Anxiety Performance of YAC128 Mice

YAC128 mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration for the purpose of evaluating the effect of the oligonucleotides against huntingtin mRNA expression on anxiety in these mice as measured by their performance in the open field and elevated plus maze assays.

Treatment

A group of seven five-month old YAC128 mice was administered 50 μg/day of ISIS 388241 delivered ICV with Alzet 1004 pumps at the rate of 0.5 μl/hr for 14 days. A control group of four YAC128 mice were similarly treated with PBS. A control group of eight non-transgenic FVB/NJ littermates were included in the study and did not receive any treatment. The mice were surgically implanted with the pumps in the following manner: Briefly, Alzet osmotic pumps (Model 2002) were assembled according to manufacturer's instructions. Pumps were filled with a solution containing the antisense oligonucleotide and incubated overnight at 37° C., 24 hours prior to implantation. Animals were anesthetized with 3% isofluorane and placed in a stereotactic frame. After sterilizing the surgical site, a midline incision was made over the skull, and a subcutaneous pocket was created over the back, in which a pre-filled osmotic pump was implanted. A small burr hole was made through the skull above the right lateral ventricle. A cannula, connected to the osmotic pump via a plastic catheter, was then placed in the ventricle and glued in place using Loctite adhesive. The incision was closed with sutures. Antisense oligonucleotide or PBS was infused for 14 days, after which the pumps were removed. The animals were allowed to recover for 2 weeks after which behavioral analysis was done and the mice were finally euthanized according to a humane protocol approved by the Institutional Animal Care and Use Committee. Brain and spinal cord tissue were harvested and snap frozen in liquid nitrogen. Prior to freezing, brain tissue was cut transversely into five sections (51, S2, S3, S4, and S5) using a mouse brain matrix. Sections 1 to 5 were approximately 2 mm apart from each other with S1 being most rostral and S5 most caudal.

Open Field Assay

Mice were placed in an open field arena (Med Associates) that uses photobeam breaks to measure horizontal and vertical movement over a 30 min test session. Data was analyzed using Activity Monitor software to examine total ambulatory movement within the arena and movement within the center of the arena as a measure of anxiety. YAC128 control mice were expected to spend less time at the centre of the arena compared to their non-transgenic, less anxiety-prone FVB/NJ littermates. The results are presented in FIG. **9** and Table 75 and indicate that treatment of YAC128 mice with antisense oligonucleotide decreased anxiety in these mice, according to the parameters of the open field assay.

TABLE 75

Effect of antisense inhibition of mutant htt mRNA on open field performance of YAC128 mice

| Mice model | Time in center (sec) |
|---|---|
| FVB control | 1326 |
| YAC128 control | 964 |
| ISIS 388241 treated YAC128 | 1433 |

Elevated Plus Maze Assay

The apparatus consisted of two open arms and two closed arms each measuring 65×6.25 cm and elevated 50 cm above the ground. Mice were placed in the center of the apparatus and their location was recorded over a 5 minute test session. YAC128 control mice were expected to spend less time at the open arms of the apparatus compared to their non-transgenic, less anxiety-prone FVB/NJ littermates. The results are presented in FIG. **10** and Table 76 and indicate that treatment of YAC128 mice with antisense oligonucleotide decreased anxiety in these mice, according to the parameters of the elevated plus maze assay.

TABLE 76

Effect of antisense inhibition of mutant htt mRNA on elevated plus maze performance of YAC128 mice

| Mice model | % time in open arms |
|---|---|
| FVB control | 32 |
| YAC128 control | 18 |
| ISIS 388241 treated YAC128 | 27 |

RNA and Protein Analysis

Total RNA was extracted from mouse brain and spinal cord with RNeasy Protect Mini Kit (Qiagen, Mississauga, ON, Canada) for real-time PCR analysis of huntingtin mRNA levels using an RNeasy Mini prep kit (Qiagen). Q-PCR reactions were conducted and analyzed on an ABI Prism 7700 Sequence Detector (Applied Biosystems). Human huntingtin mRNA levels were measured using the human primer probe set RTS2686 and normalized to peptidylprolyl isomerase A mRNA levels.

Protein lysates were prepared from mouse brain slabs as described previously (Li S. H. and Li X. J., *Methods in Molecular Biology* (2008), 217:1940-6029). Lysates were run on 3-8% tris-acetate gel and transferred using the iBlot dry blotting system (Invitrogen). Blots were probed with anti-beta tubulin (Chemicon) and mouse monoclonal EM48 antibody that reacts specifically with human huntingtin protein (Millipore). Immunoblots were quantified using Odyssey V 3.0 software.

The results are presented in Table 77 as percent reduction compared to the PBS control and demonstrate significant inhibition of huntingtin mRNA and protein levels by the antisense oligonucleotide.

TABLE 77

Percent inhibition of huntingtin mRNA in YAC128 mice

| | % inhibition |
|---|---|
| mRNA | 85 |
| protein | 86 |

## Example 16

### Intracerebroventricular Administration of Antisense Oligonucleotides Against Huntingtin in C57/BL6 Mice

C57/BL6 mice were treated with ISIS oligonucleotides via intracerebroventricular (ICV) administration to the right lateral ventricle, for the purpose of evaluating the tolerability of the oligonucleotides in these mice.

Treatment and Surgery

Groups of five C57/BL6 mice each were administered ISIS 387916, ISIS 437527, ISIS 444578, ISIS 444584, ISIS 444607, ISIS 444608, ISIS 444627, ISIS 444652, ISIS 444659, ISIS 444660, or ISIS 444661 at 150 μg/day delivered ICV with Alzet 2002 pumps at the rate of 0.5 μL/day for 2 weeks. A control group of six C57/BL6 mice were similarly treated with PBS. The procedure for implanting the pumps and oligonucleotide administration is described in Example 6.

The animals were allowed to recover for two weeks before being euthanized using isoflurane. Brain and spinal cord tissue were harvested and snap frozen in liquid nitrogen. Prior to freezing, brain tissue was cut transversely into five sections (S1, S2, S3, S4, and S5) using a mouse brain matrix. Sections 1 to 5 were approximately 2 mm apart from each other with S1 being the most rostral and S5 the most caudal.

RNA Analysis

Total RNA was extracted from anterior and posterior cortices of the brain for real-time PCR analysis of huntingtin mRNA levels using an RNeasy Mini prep kit (Qiagen). RT-PCR reactions were conducted on an ABI Prism 7700 Sequence Detector (Applied Biosystems). Mouse huntingtin mRNA levels were measured using a murine primer probe set RTS2633 and normalized to cyclophilin mRNA levels. The results are presented in Table 78 as percent reduction compared to the PBS control. ISIS 387916, ISIS 437527, ISIS 444627, and ISIS 444652 all have one mismatch with the murine huntingtin mRNA (SEQ ID NO: 3) and therefore did not show significant inhibition of murine mRNA levels compared to the control.

The microglial marker, AIF1 was also measured by RT-PCR analysis using murine primer probe set mAIF1_LTS00328 (forward sequence TGGTCCCCCAGCCAAGA, designated herein as SEQ ID NO: 54; reverse sequence CCCACCGTGTGACATCCA, designated herein as SEQ ID NO: 55; probe sequence AGCTATCTCCGAGCTGCCCTGATTGG, designated herein as SEQ ID NO: 56). The results are presented in Table 79 and indicate that the tested ISIS oligonucleotides did not induce an inflammatory response.

TABLE 78

Percent inhibition of murine huntingtin mRNA compared to the control in C57/BL6 mice

| ISIS No | anterior | posterior |
|---|---|---|
| 387916 | 72 | 74 |
| 437527 | 59 | 62 |
| 444578 | 69 | 69 |
| 444584 | 0 | 9 |
| 444607 | 59 | 79 |
| 444608 | 41 | 66 |
| 444627 | 41 | 45 |
| 444652 | 61 | 64 |
| 444660 | 35 | 33 |
| 444661 | 72 | 69 |

TABLE 79

Percent increase in AIF1 mRNA expression compared to the control in C57/BL6 mice

| ISIS No | anterior | posterior |
|---|---|---|
| 387916 | 159 | 67 |
| 437527 | 102 | 77 |
| 444578 | 22 | 7 |
| 444584 | 33 | 37 |
| 444607 | 34 | 58 |
| 444608 | 29 | 1 |
| 444627 | 46 | 22 |
| 444652 | 59 | 50 |
| 444660 | -3 | 11 |
| 444661 | 67 | 62 |

Body Weight Measurements

Body weights were measured at regular intervals throughout the study period, and are presented in Table 80. These weights were utilized as an indicator of tolerability. Mice treated with ISIS 437527, ISIS 444584, and ISIS 444652 had consistent body weight throughout the study period and were deemed the most tolerable of all the ISIS oligonucleotides included in the study. 'n/a' indicates no data for that group of mice.

TABLE 80

Body weights of C57/BL6 mice after antisense oligonucleotide treatment

| | Day 0 | Day 4 | Day 8 | Day 12 | Day 16 | Day 19 | Day 23 | Day 26 | Day 28 |
|---|---|---|---|---|---|---|---|---|---|
| PBS | 105 | 108 | 111 | 114 | 111 | 111 | 113 | 114 | 112 |
| ISIS 387916 | 107 | 108 | 106 | 111 | 106 | 104 | 101 | 101 | 97 |
| ISIS 437527 | 105 | 116 | 116 | 120 | 111 | 112 | 112 | 108 | 108 |
| ISIS 444578 | 105 | 116 | 112 | 115 | 103 | 98 | 83 | 81 | 87 |
| ISIS 444584 | 105 | 117 | 115 | 111 | 105 | 105 | 103 | 104 | 102 |
| ISIS 444607 | 105 | 115 | 112 | 110 | 101 | 98 | 106 | 109 | 106 |
| ISIS 444608 | 102 | 111 | 112 | 112 | 97 | 91 | 78 | 75 | 87 |
| ISIS 444627 | 105 | 116 | 124 | 126 | 105 | 104 | 93 | 94 | 91 |
| ISIS 444652 | 106 | 122 | 124 | 126 | 119 | 113 | 111 | 111 | 108 |
| ISIS 444659 | 105 | 118 | 123 | 116 | 92 | 89 | 68 | n/a | n/a |
| ISIS 444660 | 104 | 115 | 120 | 118 | 103 | 93 | 89 | 84 | 90 |
| ISIS 444661 | 107 | 125 | 120 | 106 | 76 | 86 | 89 | 86 | 91 |

## Example 17

### Assay for Neurotoxic Effects of Bolus Administration of Antisense Oligonucleotides in the Striatal Tissue of Rats

Sprague-Dawley rats were treated with ISIS oligonucleotides via bolus administration to the striatum, for the purpose of screening for the induction of the microglial marker AIF1 as a measure of CNS toxicity.

Treatment and Surgery

Groups of four Sprague-Dawley rats were administered ISIS 388241, ISIS 443139, ISIS 436671, ISIS 437527, ISIS 444584, ISIS 444591, or ISIS 444652 delivered as a single bolus at a concentration of 25 μg, 50 μg, 75 μg, or 100 μg.

A group of 4 rats were similarly treated with ISIS 387916, delivered as a single bolus at 10 μg, 25 μg, 50 μg, or 75 μg concentrations. A control group of 4 rats were similarly treated with PBS. Seven days after bolus administration, the rats were euthanized using isoflurane and the organs were removed. The animals were decapitated and the brain was removed for dissection of the striatal tissue. A pair of fine curved forceps was placed straight down into the brain just anterior to the hippocampus to make a transverse incision in the cortex and underlying tissues by blunt dissection. The tips of another pair of fine curved forceps were placed straight down along the midsaggital sinus midway between the hippocampus and the olfactory bulb to make a longitudinal incision, cutting the corpus callosum by blunt dissection. The first pair of forceps was then used to reflect back the resultant corner of cortex exposing the striatum and internal capsule, and then to dissect the internal capsule away from the striatum. The second set of forceps was placed such that the curved ends were on either side of the striatum and pressed down to isolate the tissue. The first set of forceps was used to pinch off the posterior end of the striatum and to remove the striatum from the brain.

RNA Analysis of AIF1 Expression Levels

RNA was extracted from striatal tissue for real-time PCR analysis of AIF1 mRNA levels. Rat AIF1 levels were measured using the rat primer probe set rAif1_LTS00219. Results were calculated as the percentage of AIF1 expression over that of the PBS control and are presented in Table 81. The results indicate that ISIS 388241, ISIS 443139, ISIS 436671, ISIS 444591, ISIS 437527, ISIS 444584, and ISIS 444652 were well tolerated in rat brain.

TABLE 81

Percent expression of AIF1 mRNA levels in vivo as a measure of neurotoxicity

| ISIS No | Dose (μg) | % increase |
|---|---|---|
| 387916 | 10 | 145 |
| | 25 | 157 |
| | 50 | 247 |
| | 75 | 316 |
| 388241 | 25 | 29 |
| | 50 | 12 |
| | 75 | 30 |
| | 100 | 41 |
| 436671 | 25 | 37 |
| | 50 | 2 |
| | 75 | 13 |
| | 100 | 50 |
| 443139 | 25 | 0 |
| | 50 | 7 |
| | 75 | 167 |
| | 100 | 26 |
| 444591 | 25 | 18 |
| | 50 | 80 |
| | 75 | 50 |
| | 100 | 207 |
| 437527 | 25 | 98 |
| | 50 | 45 |
| | 75 | 23 |
| | 100 | 126 |
| 444584 | 25 | −1 |
| | 50 | 10 |
| | 75 | 35 |
| | 100 | 31 |
| 444652 | 25 | 17 |
| | 50 | 46 |
| | 75 | 39 |
| | 100 | 48 |

RNA Analysis of Huntingtin Expression Levels

RNA was extracted from striatal tissue for real-time PCR analysis of huntingtin mRNA levels. Rat huntingtin mRNA levels were measured using the rat primer probe set rHtt_LTS00343. Results were calculated as the percentage reduction of huntingtin expression over that of the PBS control and are presented in Table 82. ISIS 388241 and ISIS 443139 are each mismatched by 6 base pairs or more with the rat gene sequence (SEQ ID NO: 5) and therefore do not show significant inhibition of rat mRNA levels compared to the control. ISIS 444584 has 3 mismatches with the rat gene sequence (SEQ ID NO: 5) and therefore does not show significant inhibition of rat mRNA levels compared to the control.

TABLE 82

Percent reduction of rat huntingtin mRNA levels in rats

| ISIS No | Dose (μg) | % inhibition |
|---|---|---|
| 387916 | 10 | 6 |
| | 25 | 39 |
| | 50 | 55 |
| | 75 | 60 |
| 388241 | 25 | 8 |
| | 50 | 23 |
| | 75 | 27 |
| | 100 | 19 |
| 436671 | 25 | 52 |
| | 50 | 57 |
| | 75 | 57 |
| | 100 | 70 |
| 443139 | 25 | 35 |
| | 50 | 29 |
| | 75 | 28 |
| | 100 | 27 |
| 444591 | 25 | 26 |
| | 50 | 57 |
| | 75 | 68 |
| | 100 | 69 |
| 437527 | 25 | 40 |
| | 50 | 55 |
| | 75 | 60 |
| | 100 | 74 |
| 444584 | 25 | 43 |
| | 50 | 38 |
| | 75 | 38 |
| | 100 | 41 |
| 444652 | 25 | 49 |
| | 50 | 70 |
| | 75 | 55 |
| | 100 | 59 |

## Example 18

### Dose-Dependent Antisense Inhibition of Huntingtin mRNA in Cynomolgous Primary Hepatocytes

ISIS 437527, ISIS 444584, and ISIS 444652 were tested in cynomolgous primary hepatocytes at various doses. The benchmark oligonucleotides, ISIS 387916 and ISIS 388241 were also included for comparison. Cells were plated at a density of 35,000 cells per well and transfected using electroporation with 39.0625 nM, 78.125 nM, 156.25 nM, 312.5 nM, 625 nM, 1,250 nM, 2,500 nM, 5,000 nM, 10,000 nM, and 20,000 nM concentrations of each antisense oligonucleotide. After approximately 16 hours, RNA was isolated from the cells and huntingtin mRNA transcript levels were measured by quantitative real-time PCR using primer probe set RTS2686. Huntingtin mRNA transcript levels were normalized to total RNA content, as measured by RIBOGREEN®. Results are presented in Table 83 as percent inhibition of huntingtin, relative to untreated control cells. Control oligonucleotide, ISIS 141923 was included in this assay and did not demonstrate inhibition of huntingtin mRNA, as expected.

ISIS 437527, ISIS 444584, and ISIS 444652 had lower $IC_{50}$ values than the benchmark oligonucleotide, ISIS

388241. ISIS 437527 and ISIS 444652 had as low or lower $IC_{50}$ values than the benchmark oligonucleotide, ISIS 387916.

TABLE 83

Dose-dependent antisense inhibition of huntingtin mRNA in cynomolgous primary hepatocytes

| | ISIS 387916 | ISIS 388241 | ISIS 437527 | ISIS 444584 | ISIS 444652 | ISIS 141923 |
|---|---|---|---|---|---|---|
| 39.0625 nM | 0 | 6 | 0 | 0 | 0 | 0 |
| 78.125 nM | 17 | 4 | 19 | 0 | 16 | 0 |
| 156.25 nM | 6 | 0 | 27 | 11 | 12 | 3 |
| 312.5 nM | 19 | 0 | 23 | 16 | 35 | 0 |
| 625.0 nM | 31 | 0 | 37 | 30 | 50 | 0 |
| 1250.0 nM | 45 | 0 | 28 | 23 | 52 | 0 |
| 2500.0 nM | 62 | 4 | 33 | 47 | 74 | 0 |
| 5000.0 nM | 78 | 54 | 55 | 42 | 86 | 0 |
| 10000.0 nM | 82 | 80 | 68 | 77 | 91 | 0 |
| 20000.0 nM | 84 | 75 | 70 | 69 | 92 | 0 |
| $IC_{50}$ (μM) | 1.4 | 5.4 | 2.0 | 4.0 | 0.8 | >20 |

## Example 19

### Measurement of Half-Life of ISIS Oligonucleotides in BACHD Mice Via Single Intrastriatal Bolus Administration

BACHD mice were administered ISIS oligonucleotides as a single bolus to the striatum for the purpose of measuring the duration of action of the antisense oligonucleotides against huntingtin mRNA expression, or its half-life, in that tissue.

Treatment and Surgery

Groups of 25 BACD mice each were treated with ISIS 388241, ISIS 436689, ISIS 436671, or ISIS 444591, delivered as a single bolus of 40 μg in a procedure similar to that described in Example 4. A control group of 25 BACHD mice were treated with PBS in a similar procedure. At various time points, 5 mice from each group were euthanized and striatal tissue was extracted. A pair of fine curved forceps was placed straight down into the brain just anterior to the hippocampus to make a transverse incision in the cortex and underlying tissues by blunt dissection. The tips of another pair of fine curved forceps were placed straight down along the midsaggital sinus midway between the hippocampus and the olfactory bulb to make a longitudinal incision, cutting the corpus callosum by blunt dissection. The first pair of forceps was then used to reflect back the resultant corner of cortex exposing the striatum and internal capsule, and then to dissect the internal capsule away from the striatum. The second set of forceps was placed such that the curved ends were on either side of the striatum and pressed down to isolate the tissue. The first set of forceps was used to pinch off the posterior end of the striatum and to remove the striatum from the brain.

RNA Analysis

RNA was extracted from anterior and posterior sections of the striatal tissue for real-time PCR analysis of huntingtin mRNA levels. Human mutant huntingtin mRNA levels were measured using RTS2617. Mouse normal huntingtin mRNA levels were measured using the murine primer probe set RTS2633. The results are presented in Tables 84 and 85 and are expressed as percent inhibition compared to the average of the PBS control group at week 1, week 10, and week 20. The half-life of the ISIS oligonucleotides in the anterior section of the brain was calculated from the inhibition data and is presented in Table 86.

TABLE 84

Percent inhibition of human huntingtin mRNA expression at various time points

| ISIS No | Time (weeks) | Posterior | Anterior |
|---|---|---|---|
| 388241 | 1 | 72 | 91 |
| | 5 | 65 | 86 |
| | 10 | 52 | 73 |
| | 15 | 26 | 56 |
| | 20 | 14 | 53 |
| 436671 | 1 | 82 | 92 |
| | 5 | 78 | 89 |
| | 10 | 68 | 82 |
| | 15 | 61 | 77 |
| | 20 | 30 | 77 |
| 444591 | 1 | 60 | 85 |
| | 5 | 58 | 76 |
| | 10 | 48 | 60 |
| | 15 | 27 | 43 |
| | 20 | 27 | 36 |
| 436689 | 1 | 72 | 83 |
| | 5 | 72 | 87 |
| | 10 | 60 | 74 |
| | 15 | 50 | 74 |
| | 20 | 44 | 59 |

TABLE 85

Percent inhibition of mouse huntingtin mRNA expression at various time points

| ISIS No | Time (weeks) | Posterior | Anterior |
|---|---|---|---|
| 388241 | 1 | 1 | 12 |
| | 5 | 22 | 36 |
| | 10 | 17 | 14 |
| | 15 | 7 | 18 |
| | 20 | 9 | 38 |
| 436671 | 1 | 84 | 96 |
| | 5 | 77 | 80 |
| | 10 | 64 | 86 |
| | 15 | 51 | 78 |
| | 20 | 19 | 75 |
| 444591 | 1 | 74 | 95 |
| | 5 | 70 | 90 |
| | 10 | 57 | 67 |
| | 15 | 34 | 47 |
| | 20 | 33 | 38 |
| 436689 | 1 | 40 | 32 |
| | 5 | 47 | 40 |
| | 10 | 35 | 18 |
| | 15 | 34 | 22 |
| | 20 | 36 | 5 |

TABLE 86

Half-life of ISIS oligonucleotides in the anterior section of the brain in BACHD mice after intrastriatal bolus injection

| ISIS No | Half-life (days) |
|---|---|
| 436671 | 46.6 |
| 436689 | 39.4 |
| 444591 | 24.3 |
| 388241 | 25.8 |

Body Weight Measurements

Body weights were measured at regular intervals, and are presented in Table 87 as a percent of the weight of the mice at the start of the study. These weights were utilized as an indicator of tolerability. There were no adverse changes in body weight in any of the mice treated with ISIS oligonucleotides.

TABLE 87

| Percent change in body weight of BACHD mice after antisense oligonucleotide treatment | | | | |
|---|---|---|---|---|
| | Week 5 | Week 10 | Week 15 | Week 20 |
| PBS | 8 | 19 | 26 | 28 |
| ISIS 388241 | 9 | 22 | 29 | 26 |
| ISIS 436671 | 5 | 19 | 35 | 38 |
| ISIS 444591 | 7 | 21 | 30 | 43 |
| ISIS 436689 | 3 | 18 | 31 | 38 |

## Example 20

### Effect of Intrathecal Administration of ISIS 437527 in Sprague Dawley Rats

Sprague Dawley rats were dosed with ISIS 437527 by intrathecal (IT) administration either as a single dose, repeated doses, or continuous infusion.

Treatment and Surgery

Rats were anesthetized with isoflurane and a 28-gauge polyurethane catheter was placed into the IT lumbar space of each rat. The proximal end of the catheter was attached to a dosing pedestal that was extended through the skin for animals in groups receiving bolus injections. The catheter for animals in the group receiving continuous infusion was attached to an ALZET pump (Model 2ML1) which was placed in a subcutaneous pocket on the dorsal aspect of each animal. Post-surgically the animals received a single intramuscular dose of ceftiofur sodium (5 mg/kg) and butorphanol tartrate (0.05 mg/kg). The rats receiving continuous infusion began receiving the oligonucleotide dose immediately. The animals that would receive bolus injections were allowed a surgical recovery period of at least five days after which the patency of the catheter was evaluated.

A group of 5 Sprague Dawley rats was administered a single bolus injection of 350 μg of ISIS 437527 delivered intrathecally. Another group of 5 Sprague Dawley rats was administered bolus injections of 120 μg of ISIS 437527 delivered intrathecally three times over the course of 1 week. Another group of 5 Sprague Dawley rats was administered bolus injections of 350 μg of ISIS 437527 delivered intrathecally three times over the course of 1 week. Another group of 5 Sprague Dawley rats was administered 50 μg/day of ISIS 437527 delivered by continuous infusion at a rate of 0.01 mL/hr for 7 days. A control group of 5 Sprague Dawley rats was administered bolus injections of PBS delivered intrathecally three times over the course of 1 week. Each group was given a recovery period of 7 days, after which the rats were euthanized. The brain and spinal cord from all groups were harvested and analyzed.

RNA Analysis of Huntingtin Expression Levels

RNA was extracted from the frontal cortex, temporal cortex, and the cervical cord for real-time PCR analysis of huntingtin mRNA levels. Rat huntingtin mRNA levels were measured using the primer probe set rHtt_LTS00343 normalized to Cyclophilin levels. The results are presented in Table 88 and are expressed as percent inhibition compared to the average of the PBS control groups.

TABLE 88

| Percent inhibition of huntingtin mRNA expression in Sprague Dawley rats | | | |
|---|---|---|---|
| Tissue | Dose schedule | Dose | % inhibition |
| Frontal Cortex | IT Infusion | 50 μg/day | 11 |
| | Single IT Bolus | 350 μg | 28 |
| | Repeated IT Bolus | 120 μg × 3 | 21 |
| | Repeated IT Bolus | 350 μg × 3 | 0 |
| Temporal Cortex | IT Infusion | 50 μg/day | 0 |
| | Single IT Bolus | 350 μg | 34 |
| | Repeated IT Bolus | 120 μg × 3 | 44 |
| | Repeated IT Bolus | 350 μg × 3 | 48 |
| Cervical Cord | IT Infusion | 50 μg/day | 22 |
| | Single IT Bolus | 350 μg | 45 |
| | Repeated IT Bolus | 120 μg × 3 | 58 |
| | Repeated IT Bolus | 350 μg × 3 | 46 |

RNA Analysis of AIF1 Expression Levels

RNA was extracted from frontal cortex, temporal cortex, and the cervical cord for real-time PCR analysis of AIF1 mRNA levels. Rat AIF1 levels were measured using the rat primer probe set rAif1_LTS00219. Results were calculated as the percentage of AIF1 expression over that of the PBS control and are presented in Table 89. The results indicate that repeated IT bolus administrations lead to inflammation at the cervical cord tissues. Continuous IT administration and single IT bolus administrations were well tolerated in the rats.

TABLE 89

| Percent expression of AIF1 mRNA levels in Sprague Dawley rats as a measure of neurotoxicity | | | |
|---|---|---|---|
| Tissue | Dose schedule | Dose | % inhibition |
| Frontal Cortex | IT Infusion | 50 μg/day | −36 |
| | Single IT Bolus | 350 μg | −4 |
| | Repeated IT Bolus | 120 μg × 3 | 41 |
| | Repeated IT Bolus | 350 μg × 3 | −7 |
| Temporal Cortex | IT Infusion | 50 μg/day | 15 |
| | Single IT Bolus | 350 μg | 22 |
| | Repeated IT Bolus | 120 μg × 3 | 25 |
| | Repeated IT Bolus | 350 μg × 3 | 76 |
| Cervical Cord | IT Infusion | 50 μg/day | 108 |
| | Single IT Bolus | 350 μg | 72 |
| | Repeated IT Bolus | 120 μg × 3 | 473 |
| | Repeated IT Bolus | 350 μg × 3 | 268 |

Example 21

Measurement of Half-Life of ISIS 436689 in the CNS Tissues of Cynomolgous Monkeys Via Intrathecal Administration

Cynomolgous monkeys were administered ISIS 436689 intrathecally (IT) for the purpose of measuring the half-life and duration of action of the antisense oligonucleotide against huntingtin mRNA expression in various CNS tissues.

Treatment

The study was conducted at Northern Biomedical Research, MI. Prior to the start of the treatment, the monkeys were kept in quarantine for a 4-week time period, during which standard panels of serum chemistry and hematology, examination of fecal samples for ova and parasites, and a tuberculosis test, were conducted to screen out abnormal or ailing monkeys. The monkeys were implanted with intrathecal lumbar catheters using polyurethane catheters connected to a subcutaneous titanium access port (P.A.S. PORT® Elite Plastic/Titanium portal with Ultra lock connector). For continuous infusion using an external pump, the animals were anesthetized to attach the dosing apparatus to the port. The animals were pretreated with atropine sulfate by subcutaneous injection at a dose of 0.04 mg/kg. Approximately 15 minutes later, an intramuscular dose of 8 mg/kg of ketamine HCl was administered to induce sedation. The animals were masked to a surgical plane of anesthesia, intubated and maintained on approximately 1 L/min of oxygen and 2% halothane or isoflurane. The animals received a single intramuscular dose of 5 mg/kg ceftiofur sodium antibiotic. An incision was made near the port for placement of the modified needle support. The modified needle was placed in the port and secured with sutures. Upon recovery from surgery, a jacket was placed on the animal.

Fifteen male cynomolgus monkeys were administered 4 mg/day of ISIS 436689 at a concentration of 1.67 mg/mL and at a flow rate of 2.4 mL/day for 21 days. A control group of 3 cynomolgus monkeys was administered with PBS in a similar manner for the same time period. Groups of 3 monkeys each were allowed recovery periods of 1 day, 2 weeks, 4 weeks, or 8 weeks, after which they were euthanized. During the study period, the monkeys were observed daily for signs of illness or distress.

All animals were sedated with an intramuscular injection of 8.0 mg/kg of ketamine HCl, maintained on a halothane or isoflurane/oxygen mixture, and provided with an intravenous bolus of heparin Na at 200 IU/kg. The animals were perfused via the left cardiac ventricle with 0.001% sodium nitrite in saline.

At the time of sacrifice, the brain was cut in a brain matrix at 3 mm coronal slice thickness. Several brain structures were sampled using a 4 mm biopsy punch. One 4 mm diameter sample from each structure was placed in 2 mL screw capped tubes containing 1.0 mL of RNAlater RNA stabilization solution (Qiagen, CA), incubated for 1 hour at ambient temperature and then frozen. Adjacent 6 mm diameter samples were placed in 2 mL screw capped tubes and frozen for pharmacokinetic analysis.

The spinal cord was sectioned into cervical, thoracic and lumbar sections, and approximately 3 mm thick sections of each area of the spinal cord were taken for RNA and pharmacokinetic analysis. These samples were processed in a manner similar to those of the brain samples.

Samples of the liver were harvested for RNA and pharmacokinetic analyses. These samples were processed in a manner similar to those of the brain and spinal cord described above.

RNA Analysis

RNA was extracted from the lumbar spinal cord, thoracic spinal cord, cervical spinal cord, frontal cortex, occipital cortex, cerebellar cortex, caudate tissue, hippocampus, middle brain, and pons for real-time PCR analysis of huntingtin mRNA levels with primer probe set RTS2617. The results measured in the various sections of the spinal cord are presented in Table 90 and are expressed as percent inhibition compared to that measured in the PBS control group at 8 weeks. The results measured in the various sections of the brain are presented in Table 91 and are expressed as percent inhibition compared to that measured in the PBS control group at 8 weeks.

TABLE 90

Effect of ISIS 436689 administered IT on huntingtin mRNA expression in the spinal cord at various time points

| Recovery period | Lumbar spinal cord | Thoracic spinal cord | Cervical spinal cord |
|---|---|---|---|
| 1 Day | 36 | 66 | 65 |
| 2 Weeks | 56 | 55 | 54 |
| 4 Weeks | 0 | 63 | 65 |
| 8 Weeks | 48 | 48 | 44 |

TABLE 91

Effect of ISIS 436689 administered IT on huntingtin mRNA expression in various brain tissues at various time points

| Recovery period | Frontal cortex | Occipital cortex | Cerebellar cortex | Caudate | Hippocampus | Middle brain | Pons |
|---|---|---|---|---|---|---|---|
| 1 Day | 53 | 37 | 8 | 21 | 19 | 24 | 22 |
| 2 Weeks | 42 | 28 | 16 | 3 | 28 | 0 | 32 |
| 4 Weeks | 47 | 32 | 25 | 7 | 22 | 2 | 43 |
| 8 Weeks | 33 | 34 | 11 | 17 | 27 | 5 | 22 |

Oligonucleotide Concentration Measurement by ELISA

Tissues (20 mg) were minced, weighed, and homogenized prior to liquid/liquid extraction using phenol/chloroform. The supernatant was removed, lyophilized, and reconstituted in human EDTA plasma (1 mL) before being analyzed using a hybridization ELISA procedure.

ISIS 436689 was detected in the tissues by hybridization to a labeled complementary cutting probe (digoxigenin at the 5' end and a C18 spacer and BioTEG at the 3' end). The complex was then captured on a neutravidin-coated plate and S1 nuclease was added to digest the unhybridized cutting probes. Since ISIS 436689 protected the cutting probe from digestion, the undigested cutting probe was used as a measure of the oligonucleotide concentration. The undigested cutting probe was detected using an anti-digoxigenin antibody conjugated to alkaline phosphatase followed by fluorogenic substrate readout. Oligonucleotide concentrations were measured in the cervical, thoracic, and lumbar sections of the spinal cord and in the liver on days 7, 20, 34, and 62 of the recovery period, and are presented in Table 92. The half-life of ISIS 436689 in these tissues was calculated from this data, and is presented in Table 93. The data indicates that the oligonucleotide was mainly concentrated in the CNS with negligible concentrations in the systemic tissues.

TABLE 92

| Concentrations (μg/g tissue) of ISIS 436689 administered IT on huntingtin mRNA expression in various tissues at various time points | | | | |
|---|---|---|---|---|
| Organ | Day 7 | Day 20 | Day 34 | Day 62 |
| Cervical cord | 118.9 | 78.7 | 79.8 | 42.8 |
| Thoracic cord | 503.5 | 215.8 | 101.6 | 61.4 |
| Lumbar cord | 557.1 | 409.5 | 143.3 | 49.5 |
| Liver | 33.6 | 10.3 | 2.0 | 0.2 |

TABLE 93

| Half-life of ISIS 436689 administered IT on huntingtin mRNA expression in various tissues | |
|---|---|
| Organ | Half-life |
| Cervical cord | 4.0 |
| Thoracic cord | 15.1 |
| Lumbar cord | 18.7 |
| Liver | 7.6 |

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gtgaatggtg tgggggctgg gaactgggac tgccaggtgt ccagcatcat tttccctttc 10020

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aactcttcct atgcccgtgt aaagtgtgtg acttggcaag gcctgtgctg catgtgacaa 10140

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tagcattctt atctgcacgg 20

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acccgtaact gaaccagctg 20

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ttccctgaac tggcccactt 20

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ctctgattcc ctgaactggc 20

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gcctctgatt ccctgaactg 20

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tgcctctgat tccctgaact 20

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attgcctctg attccctgaa 20

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gtttggaatg attgcctc 18

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gccttccttc cactggccat 20

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cctgcatcag ctttatttgt 20

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agctcttttc ctgcatcagc 20

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gtaacattga caccacca 18

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atgagtctca gtaacattga 20

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tccttgtggc actgctgcag 20

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tcattctcct tgtggcactg 20

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attctccttg tggcactg 18

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cgagacagtc gcttccactt 20

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tgtcgagaca gtcgcttc 18

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ttgcacattc caagtttggc 20

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<400> SEQUENCE: 31

tctctattgc acattccaag 20

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tttctctatt gcacattcca 20

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<400> SEQUENCE: 33

tctctattgc acattcca 18

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<400> SEQUENCE: 34

gcagggttac cgccatcccc 20

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accttatctg cacggttc 18

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ctctctgtgt atcaccttcc 20

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<400> SEQUENCE: 37

ctccgtccgg tagacatgct 20

<210> SEQ ID NO 38
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<220> FEATURE:
<223> OTHER INFORMATION: Primer

<400> SEQUENCE: 38

ggaaatcaga accctcaaaa tgg 23

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tgagcactgt tcaactgtgg atatcggga 29

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<223> OTHER INFORMATION: Primer

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aagggatgct gggctctgt 19

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<400> SEQUENCE: 42

agcaaagctt ggtgtcttgg cactgttagt 30

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cagagctggt caaccgtatc c 21

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acttcatgat gagctcggag ttcaac 26

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aggagaaaaa caaagaacac cagaa 25

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<400> SEQUENCE: 47

caattagggc aactcagaaa tagct 25

<210> SEQ ID NO 48
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ccaactggtc ccccagccaa ga 22

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cagagctggt gaaccgtatc c 21

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<223> OTHER INFORMATION: Primer

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ggcttaagca gggagccaaa a 21

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acttcatgat gagctcggag ttcaac 26

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tcctagtgtt acattaccgc 20

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ctcgactaaa gcaggatttc 20

<210> SEQ ID NO 54
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<220> FEATURE:
<223> OTHER INFORMATION: Primer

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tggtccccca gccaaga 17

<210> SEQ ID NO 55
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cccaccgtgt gacatcca 18

<210> SEQ ID NO 56
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<220> FEATURE:
<223> OTHER INFORMATION: Probe

<400> SEQUENCE: 56

agctatctcc gagctgccct gattgg                                          26
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What is claimed is:

**1**. A single-stranded modified oligonucleotide consisting of 20 linked nucleosides and having:

a gap segment consisting of ten linked deoxynucleosides;

a 5' wing segment consisting of five linked nucleosides; and

a 3' wing segment consisting of five linked nucleosides;

wherein the gap segment is positioned between the 5' wing segment and the 3' wing segment;

wherein each nucleoside of each wing segment comprises a 2'O-methoxyethyl sugar;

wherein the internucleoside linkages within the gap segment, the linkages connecting the gap segment to the 5' and 3' wing segments, and the linkages for the 5'-most and 3'-most nucleosides of each wing segment are all phosphorothioate linkages; and the internucleoside linkages connecting the rest of the nucleosides of both the 5' and 3' wing segments are phosphodiester linkages; and

wherein the nucleobase sequence of the oligonucleotide consists of the sequence recited in SEQ ID NO: 22,

or a pharmaceutically acceptable salt thereof.

**2**. The single-stranded modified oligonucleotide of claim **1**, wherein at least one nucleoside comprises a modified nucleobase.

**3**. The single-stranded modified oligonucleotide of claim **2**, wherein the modified nucleobase is a 5-methylcytosine.

**4**. The single-stranded modified oligonucleotide of claim **1**, wherein each cytosine is a 5-methylcytosine.

**5**. A composition comprising the single-stranded modified oligonucleotide or pharmaceutically acceptable salt thereof of claim **1** and at least one pharmaceutically acceptable carrier or diluent.

**6**. A composition comprising the single-stranded modified oligonucleotide or pharmaceutically acceptable salt thereof of claim **4** and at least one pharmaceutically acceptable carrier or diluent.

**7**. The single-stranded modified oligonucleotide of claim **1**, which is capable of inhibiting huntingtin expression.

**8**. A single-stranded modified oligonucleotide consisting of 20 linked nucleosides and having:

a gap segment consisting of ten linked deoxynucleosides;

a 5' wing segment consisting of five linked nucleosides; and

a 3' wing segment consisting of five linked nucleosides;

wherein the gap segment is positioned between the 5' wing segment and the 3' wing segment;

wherein each nucleoside of each wing segment comprises a 2'O-methoxyethyl sugar;

wherein the internucleoside linkages within the gap segment, the linkages connecting the gap segment to the 5' and 3' wing segments, and the linkages for the 5'-most and 3'-most nucleosides of each wing segment are all phosphorothioate linkages; and the internucleoside linkages connecting the rest of the nucleosides of both the 5' and 3' wing segments are phosphodiester linkages; and

wherein the nucleobase sequence of the oligonucleotide consists of the sequence recited in SEQ ID NO: 32,

or a pharmaceutically acceptable salt thereof.

**9**. The single-stranded modified oligonucleotide of claim **8**, wherein at least one nucleoside comprises a modified nucleobase.

**10**. The single-stranded modified oligonucleotide of claim **9**, wherein the modified nucleobase is 5' methylcytosine.

**11**. The single-stranded modified oligonucleotide of claim **8**, wherein each cytosine is a 5-methylcytosine.

**12**. A composition comprising the single-stranded modified oligonucleotide or pharmaceutically acceptable salt thereof of claim **8** and at least one pharmaceutically acceptable carrier or diluent.

**13**. A composition comprising the single-stranded modified oligonucleotide or pharmaceutically acceptable salt thereof of claim **10** and at least one pharmaceutically acceptable carrier or diluent.

**14**. The single-stranded modified oligonucleotide of claim **8**, which is capable of inhibiting huntingtin expression.

* * * * *